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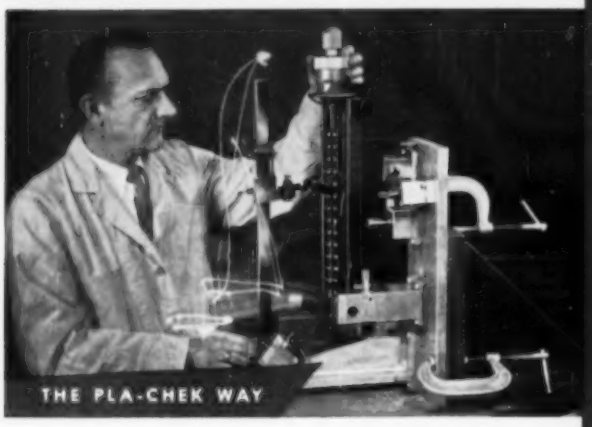
INDUSTRIAL QUALITY CONTROL

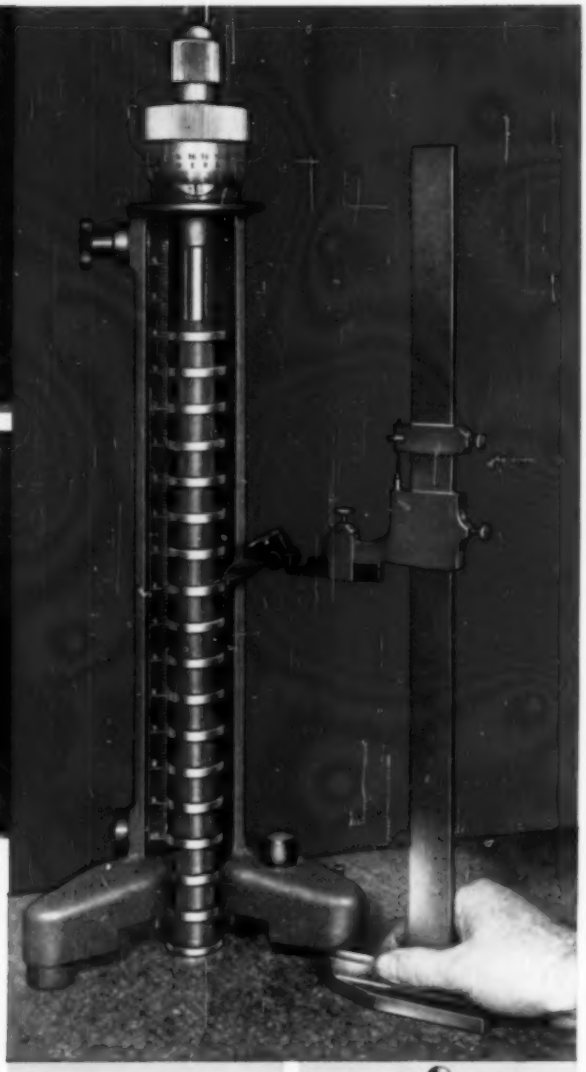
nnual ASQC Convention and Exhibition
San Francisco, California

Quality Control—the Golden Gate to Higher Profits

QUALITY
theory
Statistic
Methods

JOURNAL OF THE AMERICAN SOCIETY FOR QUALITY CONTROL





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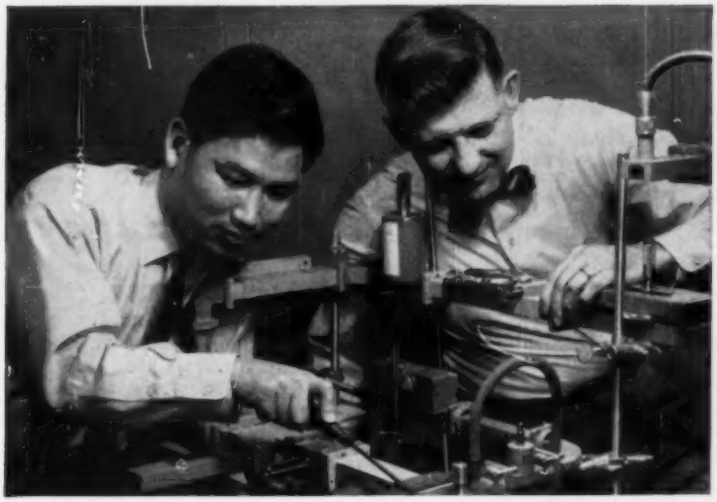

At Bell Laboratories, M. Uenohara (left) adjusts his reactance amplifier, assisted by A. E. Bakanowski, who helped develop first suitable diode. Extremely low "noise" is achieved when certain diodes are cooled in liquid nitrogen.

First practical diode for amplifier, shown here held by tweezers, was jointly developed by A. E. Bakanowski and A. Uhlir.

How basic scientific ideas develop in the light of expanding knowledge is strikingly illustrated by the development of Bell Laboratories' new "parametric" or "reactance" amplifier.

Over 100 years ago, scientists experimenting with vibrating strings observed that vibrations could be amplified by giving them a push at strategic moments, using properly synchronized tuning forks. This is done in much the same way a child on a swing "pumps" in new energy by shifting his center of gravity in step with his motion.

At the turn of the century, scientists theorized that *electrical* vibrations, too, could be amplified by synchronously varying the *reactance* of an inductor or capacitor. Later amplifiers were made to work on this principle but none at microwave frequencies.

Then came the middle 50's. Bell Telephone Laboratories scientists, by applying their new transistor technology, developed semiconductor diodes of greatly improved capabilities. They determined theoretically *how* the electrical capacitance of these new diodes could be utilized to amplify at *microwave* frequencies. They created a new microwave amplifier with far less "noise" than conventional amplifiers.

The new reactance amplifier has a busy future in the battle with "noise." At present, it is being developed for applications in tropospheric transmission and radar. But it has many other possible applications, as well. It can be used, for instance, in the reception of signals reflected from satellites. It is still another example of the continuing efforts to improve your Bell System communications.

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ARTICLES

11 Quality Control Engineering in Product Evaluation
E. G. D. PATERSON **710:70:400**
To further the professional standing and recognition of the Quality Control Engineer, the author reviews the particular function of product evaluation and analyzes the meaning and significance of the term, "Quality Control Engineering."

21 Communicating Quality Control Ideas
DAVID A. HILL **340:10:000**
The author observes that a communication is useless until it has been accepted. A communication that is not accepted may even produce positive harm. Since quality control depends on getting other people to act on the information it provides, the quality control engineer must employ communication skills.

25 Floor Control of Assembly Quality—A Practical Approach
MARK MANNING and FRED ENNERSON, Jr. **112:70:400**
It has been the writer's experience that simplicity of administration and ease of understanding must characterize a successful program for a quality control system. This article shows how one of the old stand-bys has been applied to pinpoint an operation at the first sign of trouble. It is written from the viewpoint of the man on the floor with emphasis on the operating details.

27 Weapon Systems Reliability
C. E. McLAUGHLIN **800:60:900**
The author discusses specific quantitative requirements for reliability which are meaningful and realistic. Mr. McLaughlin makes a few suggestions as to how his problem might be approached in practice and comments on some of the contractual aspects.

30 Statistical Quality Contrel and Reliability
HAROLD R. KELLOGG **100:800:60:70:400**
Much of industry has made a very costly error in failing to recognize the research, development, and control potential which Shewhart so clearly visualized in Statistical Quality Control. The demands of industrial automation and of space exploration now make it essential that industry realize that Statistical Quality Control provides the only known path to reliability.

35 A Reconsideration of the Variables Control Chart, with Special Reference to the Chemical Industries.
RICHARD A. FREUND **111:70:000**
A review of the fundamental assumptions of the Shewhart system is undertaken in order to contrast the purposes of the Shewhart Control Chart with those of the Acceptance Control Chart. This review is followed by a description of the Acceptance Control system and a specific detailed example of its application.

42 Management Looks at Quality Control
GEORGE A. PECK **300:10:400**
Today there are many forces at work which will change the world of tomorrow. No one can continue his present way of life without considering what effect these forces may have upon him or his security. The author considers some of these forces and their possible effects.

48 Critical Σd^2 Values for Rank Order Correlations
KLARE L. TEEGARDEN **533:60:70:400**
The rank order correlation coefficient may be used to save time in preliminary analysis since we are "searching" rather than seeking the accuracy that would be obtained by Pearsonian correlation coefficients.

DEPARTMENTS

From the President's Desk 10
14th Annual Convention and Exhibition Program 50
Mid-Pacific Conference Program 55
Book Reviews 56
What's New? 58
Section Briefs 64
Clinics, Conferences, and Courses 71
Section Calendar 76
ASQC Announces 77
Product Education Service 78
Positions Available 79
Consulting Services 80

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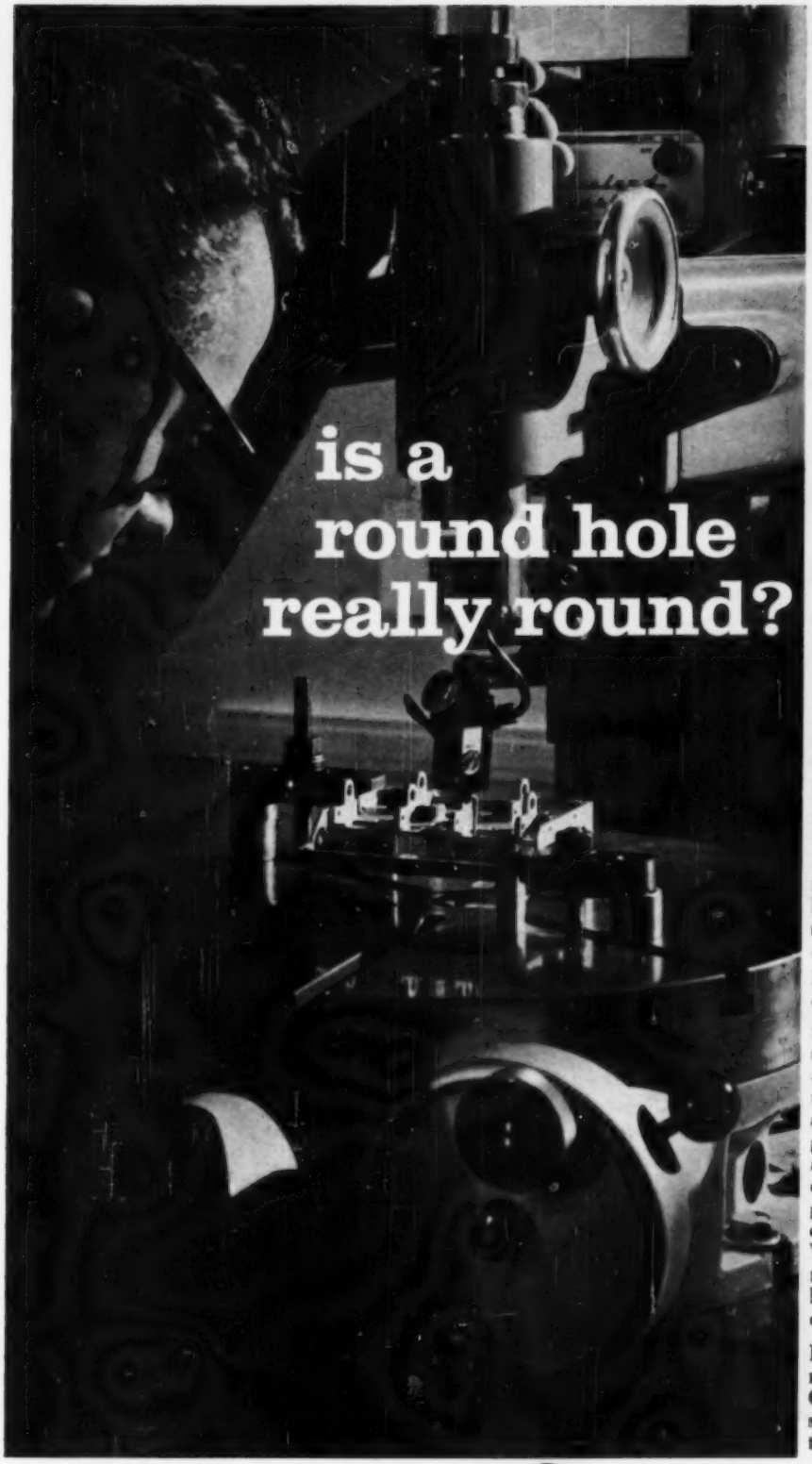

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proved reliability you can build around

New John Deere Single-Stick Crawler does more work "singlehanded"

Instead of two steering levers and a direction reverser lever, John Deere's revolutionary new crawler has a single stick that takes over all three functions of these controls. One hand operates the tractor—steers it left and right, shifts it forward and back. There's not only less operator fatigue, but less lost motion—the right hand never needs to leave the equipment controls. The result—faster work and higher production at lower cost.

John Deere's development of single-stick crawler control reflects a broad and intensive policy of design and manufacturing improvement. It clearly indicates the Company's understanding of the increasing demands made upon industry today. This advance is just one significant result of the continuing efforts being made to answer these growing needs most effectively.

Operate crawler with left hand—control loader bucket with right—save time!

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From the President's Desk

Reliability

IN RECENT months increased attention has been given to this matter of reliability of industrial product—commercial, military and experimental, this attention stemming in a large measure from the profound effects of the very substantial economic factors that relate so closely to this important quality characteristic—reliability. How to improve it—this is the problem. The efforts of many are currently devoted to seeking satisfactory solutions. Thus we find within industry groups of people eager to learn of these solutions and to apply them, and to share their experiences with others for the common good, the essential ingredients of a purposeful and useful professional technical society.

A basic purpose of the American Society for Quality Control is

> ". . . to create, promote and stimulate interest in the advancement and diffusion of knowledge of the science of control and its applications to industrial, administrative and other processes, especially to the quality of industrial product."

The Society has from its beginning held that "quality of industrial product" refers to all types of products and to all product characteristics that contribute to continuous customer satisfaction. Such characteristics, so aptly described by Dr. Walter A. Shewhart many years ago by his SADE-Q—satisfactory, adequate, dependable, economic Quality—inevitably includes satisfactory performance during the intended life under expected conditions of use, as well as such other characteristics as ease of operation, maintainability and serviceability. Moreover, the "science of control" is a broad discipline, requiring the development of tools for measuring, specifying, standardizing, evaluating and improving such product characteristics and encompassing the use of such tools in both the design and production processes.

Of late, the names "Reliability" and "Reliability Engineering" have become attached to certain engineering activities that apply the "science of control" primarily to product design characteristics relating to satisfactory performance. In recognition of the growing importance of and interest in these activities, the Board of Directors has authorized the establishment of a Reliability Engineering Technical Committee to the end that the basic purpose of the Society as set forth above shall be met with respect to the knowledge of these activities and the tools thereof. The Committee will strive to represent the interests of all segments of industry and will cooperate with other professional societies having similar interests in this quality characteristic.

THANKS to the continuing efforts and the hard work of a number of Society members, an Ad Hoc Committee on Reliability during the past year has laid a solid foundation on which the new Technical Committee can build. Formal organization of the Committee will take place at San Francisco; a meeting is scheduled for Wednesday, May 25, at 9 a.m. You will recognize this date as the second day of our 14th Annual Convention, to be held at the Sheraton-Palace Hotel.

There is much work to be done by the Committee in strengthening and adding to the activities already under way. If you are interested in this subject of Reliability Engineering and would like to take part in professional pioneering in this field, you are cordially invited to attend this meeting.

Please notify W. A. MacCrehan, acting chairman, in advance, of your intention to attend. If you cannot be present but are actively interested in the work of the Committee, let him know. Address your communications to Mr. MacCrehan at Society Headquarters, Milwaukee.

Reliability—a challenge to all concerned with control of product quality!

C. E. Fisher

QUALITY CONTROL ENGINEERING IN PRODUCT EVALUATION

E. G. D. PATERSON

Bell Telephone Laboratories, New York, N.Y.

This is the last of a series of papers on Quality Control Engineering sponsored by the ASQC Committee on Professional Development. While it is intended to cover one aspect—product evaluation—of the over-all quality control function, the primary purpose of each of the papers is to further the professional standing and recognition of the quality control engineer. To this end, therefore, as well as to the objective of defining the over-all operational framework within which we are to review the particular function of product evaluation, it is first necessary that we agree upon what we mean by the term Quality Control Engineering. That there exists a lack of common understanding in this respect is attested by the fact that, under the title "Total Quality Control," the first paper in this series is directed to a description of the over-all quality control function. (See also Reference 1).

One may ask why, especially when the first of this series of papers is directed toward describing specifically the elements of the over-all function, it is proper, as a preamble to a discussion of one of these elements—product evaluation—to make more than passing reference to the whole field. Aside from the fact that we are still in the realm of opinion in this respect, justification is found in the extreme importance of reaching general agreement as to what the job is and what kind of people are required to execute it. Only after such agreement can we determine whether the work is at the professional level, and whether its practitioners are in fact, or should be, qualified engineers in the sense defined by legal licensing requirements. Any material which facilitates this agreement justifies itself on the basis of emphasis, if it is repetitive, and under the guise of clarification, if it is helpfully explanatory.

Historical Background

It appears to be timely and appropriate under the circumstances, therefore, to review some pertinent historical facts which may not be widely known. As far as the author is aware, the Bell System, and more

Editorial Note

This article by Mr. Paterson is the sixth and last in the series of Professionalism in Quality Control," articles.

The series includes "Professional Quality Control Engineering," by A. V. Feigenbaum, General Electric Co.; "What ASQC is Doing for the QC Engineer," by Leon Bass, General Electric Co.; "Quality Control Engineering in New Designs," by W. J. Masser, General Electric Co., and "Quality Engineering Applied to Incoming Material," by David A. Hill, Hughes Aircraft Co., and "Quality Control Engineering in Product Evaluation," by E. G. D. Paterson, Bell Telephone Laboratories.

MEW

ASQC LCS Code 710:70:400

particularly Bell Telephone Laboratories,* is considered to be the originator of that specialized quality activity which today we refer to as Quality Control in its broader interpretation. It is significant to note that this activity was launched under the then new title "engineering inspection." The breadth of the work envisioned is indicated by the following quotation from a short two page descriptive article which appeared in the August, 1926 edition of *Bell Laboratories Record*:[2]

> "In the advance of science new fields of activity open, to which new names must be applied . . . . Engineering, the art and science of making useful to man the materials and energies of his surroundings, envelopes the more routine art of inspection; and inspection which is carried out for engineering purpose, becomes engineering inspection.
>
> . . . . "In order that engineering inspection shall be of greatest value there must be an art and science of inspection engineering. The pure sciences of mathematics, physics, chemistry and the like must be applied to the problems of inspection in the same spirit and with similar research point-of-view as guide their application to development and design.
>
> ". . . . and within our Laboratories, inspection engineering, carrying also a responsibility for quality over-sight and criticism, is assigned to a separate department. The duties of the department are closely inter-related with those of the development departments and certain technical groups in the Western Electric Company. With proper interpretations they are described as follows:
>
> 1. To develop the theory of inspection: putting existing mathematical knowledge into available form for use in laboratory and factory, and developing new principles where existing knowledge is inadequate.
> 2. To develop methods of stating the quality of various types of apparatus and switchboards, and methods of applying these concepts in every-day work; to develop economic standards of quality which telephone materials should meet.
> 3. To maintain oversight of the quality of apparatus, supplies and systems currently being furnished for communication service; to make regular reports on the current quality of these materials.
> 4. To study the quality and performance of telephone plant in service as an aid to further and improved developments; to give special study to instances where unsatisfactory quality is reported and to guide the steps taken to prevent recurrences of such cases."

Now bear in mind that this article was written in the year 1926, some two years after the program had been initiated. Viewed in the light of the circumstances of its time, this new "art and science of inspection engineering" represented a veritable "break-through," both in the approach to quality control and in scientific management. If we review carefully the duties outlined, properly interpreting the language as admonished by the article, we recognize as broad a charter for quality control as has yet been claimed by its most ardent advocate. In any event this charter was sufficient to inaugurate a comprehensive quality program which deals with specific phases such as standard setting, scientific inspection, sampling, process control, experimental design, nonconformance handling, quality survey, service performance oversight, complaint investigation, quality evaluation and reporting, inter-phase feedback, and, if the implication is not already sufficiently strong to encompass it, reliability, as has been elsewhere cited.[3] Note also that this program was to be carried out in such manner as best to serve the over-all economy of the Bell System. Although some of us, who have spent our life's work in this broad field, can scarcely look upon it as a "new concept"[4] of the 1950's, we can certainly welcome the strong endorsement implied by its independent development and espousal.

The old adage "handsome is as handsome does" applies significantly in our desire to label our members as professionals. Especially is this true when we have in mind their licensing as Professional Engineers. It is the people, not the job, who are licensed. Let us, therefore, review the type of people who were contemplated as suitable to carry on the work of the "inspection engineer." In a further quotation from the same Laboratories' *Record* article[2] we find that

> "The fulfillment of these duties requires men of many talents: experts in glass, metals, wood, leather, paper, textiles; engineers experienced in design, manufacture, and operation. Each endeavors to know all that is of engineering interest throughout the history of the design, production, and use of the apparatus or systems in which he specializes . . . They have no separate laboratories, no individual problems apart from the broad problem of contributing, through cooperation, towards the best telephone instrumentalities which present day science and economics admit."

Recruited to man the organization established to carry on this work were professional people, mostly from the design, development, and research area, together with a few, who were themselves engineers, from the existing "Inspection" Department of the Western Electric Company. Have in mind that Bell Laboratories has only one general occupational classification for its professional technical personnel. They are all Members or Associate Members of the Technical Staff, whether they be physicists, mathematicians, or chemists, or whether they be professional engineers, and so licensed, as some are, and some are not. Thus to insure that the caliber of activity carried on in the Inspection Engineering Department would be, as it was calculated to be, at the professional level, professional people were selected at the outset to prosecute it.

It is well to be more specific in order to emphasize the professional character of the work and the workers. Heading the Department with the title "Inspection Engineer" was R. L. Jones, now deceased. Unknown, perhaps, to many of you, although mentioned in the preface of Dr. Shewhart's text[5], he was previously in charge of transmission engineering, author of the *Record* article referred to, one of the first to be awarded the degree, doctor of engineering, by M.I.T., subsequently vice president of Bell Telephone Laboratories, and, in the author's considered opinion, the person who, more than any other single individual, was responsible for conceiving and initiating development of the broad quality function to which we today address our attention.

Among those under his direction, and known to

*Bell Telephone Laboratories was incorporated in 1925, succeeding the enginering department of the Western Electric Company. The latter, as the manufacturing and supply unit of the Bell System, currently has its own Quality Assurance organization with which Bell Laboratories Quality Assurance maintains very close liaison, and from which it obtains inspection results on communication product for the System.

most of you, were such people as George Edwards, previously a transmission engineer, widely known for his outstanding leadership in the Quality Control field, Director of Bell Laboratories' program in this area for many years until his retirement, and first President of the American Society for Quality Control; Walter Shewhart, internationally recognized as a statistician, inventor of the control chart, and author of the now classic "Economic Control of Quality of Manufactured Product"; Harold Dodge, engineer, statistician, author, now professor, and widely famous for his sampling and quality rating developments; and Donald Quarles, teacher, engineer, later vice president of Bell Laboratories, president of the Sandia Corporation, and more recently Deputy Secretary of Defense. The organization was shortly augmented by such well known ASQC members as Paul S. Olmstead, Harry G. Romig, and Miss Mary N. Torrey.

The character of a job is largely determined by the type of people who carry it on. The formal quality program at Bell Laboratories was of professional caliber from the day it started. It was by design, not accident, that the supporting personnel selected were all professional. The majority were educated and trained in engineering. Indeed, a substantial part of the author's own engineering experience, necessary for qualification for the Professional Engineer's license, was gathered in this Department; *buttressed*, of course—and this is very important—*by the specialized knowledge required for license in any branch of engineering.* Thus as a Quality Specialist,* the author qualified for Professional License in electrical engineering.

In this connection, it is unlikely that a State will grant a license in quality control engineering unless the applicant demonstrates his ability, by education and experience, to protect the public welfare and safety. Let us keep in mind that, as with a physician's, the engineer's license usually permits the recipient wide latitude in his authority to practice engineering. Its possession carries with it the implication that he is qualified to judge, and ethically so constituted as to confine his activities to, those fields in which he is professionally competent.

All things considered, it is the author's opinion that professional recognition of the Quality Control engineer will be advanced most rapidly when he possesses a broad engineering background which satisfies at least the current minimum requirements for Professional Engineering license.

Quality Control Is A Broad Engineering Function

Referring again to Dr. Jones' article, it is significant to note that there was no mention of either the word "statistics" or the term "quality control." He referred to the activity which he envisaged as a new branch of *engineering*. What he said was, in effect:

> There is some method—better than the "horse-and-buggy" type of inspection—which should supplement the already recognized efforts of the designer, the producer, and the inspector to evaluate, control, and economically maximize product quality. I conceive it to be a new and separate, but mutually cooperative, branch of engineering. Apply your joint and several professional talents to develop it. organize it, and prosecute it to the end of attaining the highest quality of telephone product economically possible.

*In Bell Telephone Laboratories the Quality Control engineer is frequently referred to as a "Quality Specialist" since he directs his efforts primarily to a particular type of product which is referred to as his "specialty."

Liberally paraphrased though this may be, the author's contemporary discussions with Dr. Jones, and his personal observation of the program's development, convince him that this was essentially the nature of the project which Dr. Jones had in mind.

It was thus as his contribution to this challenge, and as a part—a vital part—of the complete program that Dr. Shewhart had developed the control chart—a technique finding its place in his over-all statistical control philosophy. Statistics thus provided a scientific tool, a means-to-an-end, a *sine qua non*, perhaps, but not the complete *corpus* of the quality control system. Dr. Shewhart himself was well aware of the part that engineers must play in helping to bring to practice the fruits of his own efforts. In developing his theories, he was always solicitous and considerate of the reactions of the pragmatic, earthy, skeptical engineers. If contemplation does not convince, experience demonstrates that the phenomenological aspects of all phases of quality control are fundamentally engineering—in import, approach, and treatment.

Widespread and rapid recognition and growth in certain phases of quality control were largely sparked by the "barnstorming" program (1942) of those who may be regarded as the "three musketeers" of statistical quality control—George Edwards, Harold Dodge, and Rupert Gause (the latter then with Army Ordnance, now with Bell Laboratories)—undertaken at the request of Army Ordnance and with the wholehearted support of General Leslie Simon, a recognized authority on, and ardent proponent of, quality control. However, the breadth of their expository and training activities was severely circumscribed by the exigencies of World War II and the need to concentrate on those particular phases of quality control which could be quickly and widely applied by the Armed Forces in their procurement program so as to provide a maximum of results within a minimum of time.

Similar limitations applied, in general, to the programs exemplified by the "eight-day" courses given under the auspices of the War Production Board which did so much to initiate a widespread interest in quality control. Perhaps the necessarily restricted effort and the ever-present semasiological uncertainty associated with the words "quality control" led to the unfortunately narrowed connotation which some now attach to the term "Quality Control."

The limb has been mistaken for the whole body!

Bell Laboratories had long since recognized the descriptive shortcoming associated with the term "engineering inspection," had avoided as inadequately definitive the functional title "quality control," and had coined the term "quality assurance" which, being new and hitherto undefined, permitted the broad connotation with which Laboratories intended to associate it. For those who have not already done so, a reading of the paper "Quality Control in Electronics"[6] should prove to be timely and informative. A review of the literature covering quality control by an author well acquainted with its practice, it points out the intent to attribute to the term a broad quality-assuring function. Similarly, a series of two articles which appeared in "The American Statistician" covers development of Quality Control in the United States over a twenty-five year period.[7]

In his AMA management report paper[8] Dr. A. V. Feigenbaum points out that

> ". . . . many businesses over the years have attempted to centralize their company quality responsibilities by organizing a function whose job has been handsomely described as 'responsibility for all factors affecting product quality.' These experiments have had a lifespan of as long as six to nine months—that is, when the job incumbent has the advantage of a strong stomach, a rhinoceros hide, and a well-spent, sober boyhood. Others not similarly endowed did not last the six months. The simple fact of the matter is that the marketing man can best evaluate customers' quality preference, the design engineer can most effectively establish specification quality levels, and the shop supervisor can best concentrate upon the building of quality."

In other words, "each to his last"—most emphatically not *"chacun a son gout!"*

Secure in the possession of a goodly portion of each of the three advantages enumerated—undisputed as necessary qualifications for any durable quality control engineer—and fortified by the further advantage of over a third of a century in the practice of the function described, perhaps handsomely but not entirely fancifully, as "responsibility for all factors affecting product quality," I feel a strong temptation to vouchsafe agreement (with proper interpretation) with the unidentified author of the quotation. Were one to be permitted the liberty of inserting the article "a" before "responsibility," temerity might give way to smugness. Indeed, having myself used such descriptions as "an over-all review of all factors relating to quality—to the end of getting it and keeping it where it should be" and a "cradle to grave process,"[2] I must rise to my own defense. Agreed that the marketing man can best evaluate customers' quality preferences; the Bell System has highly skilled (and professional) groups for just this purpose. It is not true, nevertheless, that the quality control engineer has a responsibility for knowing this preference, for evaluating it in conjunction with, or at times in terms of, the many specified and measurable quality characteristics, and for directing his efforts towards its attainment? How else would he be able properly to discharge his obligations in setting acceptance criteria, disposing of non-conforming material, reporting on product quality, and initiating any necessary corrective action. I must disagree categorically with the idea that the design engineer can most effectively, or should, establish the quality levels, if to "quality levels" we attribute the meaning most commonly associated by the quality control engineer. Finally, one need merely pose the question whether the shop supervisor concentrates on the building of quality with a motivation entirely uninfluenced by his Shop Quality rating.

Now I am sure that Dr. Feigenbaum—whose status as an expert is well secured and who has done so much more than I to spread the broad-concept gospel of quality control—does not find himself in basic disagreement. I indulge this pseudo-facetiousness only as an aid to clarification and to expose the ease with which we presumed experts can maneuver ourselves into an exercise of semantic parry. It is well to remember that the quality control engineer is (at least in the Bell System) authorized to establish acceptance standards, to specify how product compliance with these shall be determined, and to decide whether product which fails to meet these standards in any respect may or may not be shipped. To associate with such authority a concomitant broad-scale responsibility for quality should not over-stress one's credulity.

What is Meant By "Quality"?

It is as a part of this very broad concept of quality control that I wish to discuss one of its phases—product quality evaluation. It will be helpful first to consider briefly just what we mean by the term quality insofar as it relates to our field of activity.

Dictionary definitions, of which there are many, fall short of filling our specialized needs. In its ordinary usage a quality is one of a number of attributes or characteristics which, when integrated with others, make an object "what it is" or give it an "over-all quality." It is frequently associated with adjectives such as good, fine, high, etc. which, in the advertising business, seem to appear almost invariably in their superlative forms. Its constituents are often of an abstract nature which defy quantitative measure—style, feel, appearance, workmanship, "the quality of mercy is not strained."

In our area of interest, fortunately, we are more often concerned with the utilitarian and more readily measurable qualities which determine such characteristics as operability, efficiency, reliability and life. Nevertheless, such features as the "appearance," "feel," "balance," "fit" and "style" of a telephone handset, for example, are important and much thought, time, and talent have been expended to optimize them. We are not always in a position to neglect the intangibles.

Offhand, one might expect to find the answers to the problem of defining and evaluating quality in the design specification. How else, one might ask, could a product embodying the design intent be brought into being? Certainly, we are warranted in assuming that limits for each of the desired quality characteristics are specified therein or reasonably well implied. And certainly, in the absence of any contradictory information, we should be free to restrict our concern to the particular qualities covered. None know better than we, however, that no two things can be made exactly alike. Hence, no two things have exactly the same quality. Our problem would be simpler, moreover, if it were confined to comparing, and compositely evaluating, product of closely similar characteristics. Actually, we are frequently in need of some form of quality common denominator among items which appear not to have the remotest relationship one to the other, at times, it seems, almost as heterogeneous as the alleged ingredients of the male juvenile—"snips and snails and puppy dogs' tails."

As background for our discussion, let us review for a moment the pertinent quality characteristics of two typical products.

Let us take first a very simple one—a sash-weight intended for use as a counter-weight for a double-hung window. To function properly, it must have such shape and dimensions as will insure its freedom to move in the ample slot space provided for it. It must have a relatively high specific gravity in order to reasonably limit its volume. It must have sufficient compression, bending, and impact strength to withstand handling and shipping; tensile strength a little, but not much greater than the sash cord with which it is to be associated; and a surface configuration and smoothness adequate to avoid handling hazards. It must provide an indefinitely long service-life and it must be cheap. It must have a weight somewhat less than that necessary to balance half the weight and friction effects of the window sash; and its weight

must be sufficiently well controlled so that, when associated with its randomly selected balancing partner, no cocking of the sash results. It must be so constituted as to insure freedom from maintenance, since its position in service is relatively inaccessible. Hence its arrangement for attaching the sash cord must be such as to insure the latter's freedom from wear. While it is an end product, note that it functions as part of a system, and that the system requirements have largely dictated its individual properties.

Consider another simple but somewhat more operationally sophisticated item—the circular disc which constitutes the diaphragm of a telephone receiver. To fulfill its function as a magnetic-mechanical acoustic transducer, it must have the physical properties which insure a faithful response to the electrical input signal over a frequency range of several thousand cycles per second. (Its acoustical output is, of course, greatly influenced by other parts of the receiver). Its composition and its dimensions are critical. Changes in its characteristics with temperature must be small or suitably compensating. It must resist the fatiguing effect of the millions of vibrations imposed during its expected service life. It must function compatibly with others of the receiver's components which themselves are variable. It must be interchangeable with other diaphragms of its contemporary manufacture. It too, like the sash-weight, must provide a long life in normal service, and it too must be cheap.

Unlike the end-product sash-weight, the receiver diaphragm is only one component — a piece-part of the receiver. Yet its design and quality considerations are closely associated with its parent receiver, which in turn is part of the telephone set, which is connected through a transmission medium to the complex switching system of the central office whence, through a similar transmission system and another telephone set, it receives, with the aid of the central office power battery, the electrical replica of the acoustic signal emitted by the talking party. (This description impresses one as a technical parody on the humorous—including the humerus—spiritual describing the desiccated osteological articulation of the human).

Since I am not a "quality specialist" in respect to either sash-weights or receiver diaphragms, the foregoing analysis of their respectively necessary quality characteristics may be presumed to be incomplete. Yet it will demonstrate the many design (and quality) considerations which are involved in even the apparently simple items; and it will demonstrate, in particular, the type of thinking which is preliminary to the exercise of any one of the quality control activities.

To lay out and prosecute properly the quality control program, it is vital that the quality control engineer have a thorough technical knowledge concerning the particular product involved; he must be familiar with and understand not only its design but its design intent as well. If he does not already possess such specific knowledge, he must acquire it; and to acquire it he will usually need a sound, basic, technical training. This is illustrated in the following excerpt from an article describing Laboratories' Nike Quality Assurance program:[26]

> "The Nike missile is a complex electromechanical device and, while our quality assurance engineers have had wide experience with such devices, the missile introduced to them new physical interrelationships and, in particular, new aerodynamic and ambient environments. It is axiomatic with us that our quality specialists must be familiar with the design, function, manufacture, inspection, and use of their specialties."

Quality Evaluation

At the outset, let me make it clear that in the material to follow, I have attempted primarily to discuss the type of thinking and rationalization processes involved in product evaluation. I have purposely avoided either prescribing or delineating any specific operational plan, and I do not mean to imply that any operational procedures which I may suggest are necessarily an actual part, or are handled precisely in the manner indicated, in any existing evaluation plan. There is a relative dearth of literature on this subject and, until the results of more widespread experience in this area are forthcoming, it would be unwarrantably presumptuous to be overly didactic.

The character of the comments and questions from several of my colleagues after their reading of my first draft of this paper convinced me that I was not warranted in assuming that all of us attach one and the same meaning to the term "quality evaluation." My somewhat indiscriminate use of the term "quality evaluation" and "quality rating" had led to confusion. Toward a better common understanding therefore, let us review some of the factors involved in any attempt to "evaluate" quality.

Basically, we, as quality control engineers, are concerned with that interpretation of the word "value" which represents a measure of the degree to which a product satisfies or fulfills an economic need or want. This economic need or want cannot ordinarily be defined by a single attribute of the product. One is usually interested in how a pair of shoes "look" and "feel" as well as how they wear. Moreover one's concern with respect to these characteristics may vary from person to person, from time to time, and with circumstances.

The farmer in the field values his working brogans above dress shoes. We all recall the oppressed equestrain willing to exchange his kingdom for a horse—an excellent illustration of the value of time and place utility.

Not only is "value" a relative term, but most of those of its constituents which are subjective in nature do not lend themselves to physical measurements. The "value" of a product is thus relative, subjective, a function of time and circumstance, and an assessment which cannot be expressed as a single quantity. Despite the misgivings which these limitations engender, the job of quality evaluation is not altogether hopeless from the standpoint of the quality control engineer.

For purposes of our discussion, we can divide the problem of quality evaluation into two categories: (1) the assessment of those features which determine the customer's preference for, or the economic superiority of, product A over a similar product B; and (2) the assessment of the variations in relative quality of a product of essentially the same design, from unit to unit, or lot to lot, or time to time. In either case, we may be interested in an individual quality characteristic, or in the over-all quality which results from the combined effects of all of the characteristics.

In the first category, we may compare Fords with Plymouths and Chevrolets, or the 1958 model with the 1959 model. In the second category, we may compare 1959 Fords made today with those made yesterday. In the first case, we are concerned not only with variations from one Ford to the next but, more par-

ticularly, with basic differences between makes or models. In the second case, such basic differences are not involved.

While the quality control engineer is interested in both categories of evaluation, prior decisions on the part of the market analysts and research and development engineers will have essentially fixed the basic designs, and thus the broad quality differences envisioned in the first category. Quality evaluation in this more fundamental area involves so many nontechnical variables that, so far as I am aware, no broadly applicable, quasi-quantitative procedures have been developed for the purpose. Quality evaluation of the type included in the second category, however, is a procedure which more easily lends itself to formalization, is the process commonly understood by the term "quality rating," and is normally part of the assigned responsibility of the quality control engineer. It is this latter type of quality evaluation which I will discuss in some detail.

Quality Rating

The over-all quality of the sash-weight, or the receiver, is a complex composite of many separate contributory quality characteristics, each of which is itself a variable—not usually an independent variable—and each of which has a significance depending largely on the assembly or system of which the individual product is a part. Thus the measure of the composite quality of an individual unit of product may not only have any one of a potentially infinite number of values, but its relative importance may also depend upon the particular qualities of a large number of separate and dissimilar products with which it is to be associated. The designer must recognize these relationships and potentialities and specify suitable requirements for the individual unit to assure satisfactory performance. For quality rating purposes, the quality control engineer must not only recognize these relationships, but must attempt to take into account quantitatively their related importance to the over-all quality of the product. He must do this in a manner which reconciles the intent of the designer, the problems of the producer, and the desires of the consumer, and in a manner which recognizes the exigencies of, and accords full importance to, economic costs.

The over-all product quality, and its constituent characteristics, are usually not specified in terms associated directly with the ultimate consumer's expressed desires. The consumer wants a telephone which reproduces the voice "clearly" and "naturally." He wants an automobile which will accelerate rapidly, provide so many miles per gallon of fuel, ride comfortably, and have a pleasing appearance. The designer specifies limiting values for the volume response of the receiver over an appropriate range of frequency under prescribed conditions of input. For the automobile, he specifies torque, power, etc. (these in turn, are usually insured by other engine design requirements) to control engine performance; weight distribution, spring characteristics, etc. to control riding qualities; and dimensions, materials and processes to control shape, style, and finish.

It is customary, and quite proper, for the quality control engineer to assume initially that the basic quality considerations are appropriately defined, circumscribed, or implied in the design specifications. He may subsequently find this assumption to be unwarranted in some instances—that the specifications are inaccurate or, more frequently, inadequate in some respect. Review of the design specifications for just this purpose is a part of another phase (quality survey) of quality control. In the event of such error or inadequacy, the remedy is obvious, though not always simple. At any rate, the point to be kept in mind by the quality control engineer is that, while the specified characteristics normally provide the basic parameters by which quality is to be evaluated, the significance of the quality characteristics should be measured in terms of their ultimate effect on service performance in which they fulfill a "means-to-an-end" function. This, of course, involves a problem of weighting.

Because the complexity of quality rating increases rapidly with the increase in the number of qualities to be measured and combined, there is a strong incentive to minimize the number of characteristics to be treated as independently significant for quality rating purposes. Whatever can be done to select one characteristic as representative of several others with which it is sufficiently well correlated—or to eliminate entirely attention to individual or over-all qualities which can properly be assumed to be fixed for rating purposes—will greatly simplify the evaluation process. This applies particularly to piece-parts or components which function "passively," (this term being construed for present purposes in the lay sense to include structural parts such as framing, screws, insulators, etc., but not circuit components so characterized in the more specific technical connotation).

The telephone receiver diaphragm, for example, is characterized by material and dimensions. The material, in turn, is dependent upon raw constituents and processing, the latter involving mixing, metallurgical and mechanical processing, and heat treatment. If we can assure that the material, in the comprehensive sense indicated, is uniform and correct, then the magnetic-acoustic properties of the diaphragm itself may be related exclusively to dimensions. If these in turn, can be sufficiently well controlled, we are warranted in omitting individual quality evaluation of the diaphragm and in confining attention to the quality of the receiver of which it forms a part. It requires little imagination to visualize the practical impossibility of rating the quality of each characteristic of each part of each product of the total output of a large enterprise.

The first problem, then, is to determine to what detail it is necessary, and practically reasonable, to go in order to insure an adequate and dependable quality rating program. On the one hand, we are constrained by the costs involved in meticulous attention to details; on the other, we are urged by the specter of the potentialities of oversight. The undetected omission of the specified heat-treatment of the clamping screws in the spring pile-up of a relay, and their subsequent "head-popping" as a result of the hygroscopic expansion of the pile-up separators under humidity in service, completely vitiates the carefully compiled quality evaluation of the relay based upon its dynamic end-tests in the completed state. This problem as to how far to go in the selection of pertinent quality information for evaluation purposes calls for the highest degree of engineering judgment, a judgment which results from the quality control engineer's "endeavor to know all that is of engineering interest throughout the history of the design, production, and use of the apparatus or systems in which he specializes."[2]

From what has been said, it follows that one, if

not necessarily the only, technique of rating the quality of an individual unit of product is to measure the actual values of the several carefully selected characteristics, weight each of these values by a factor which takes into account both its variation with respect to its own norm or standard and its significance with respect to the other characteristics, and finally to combine the weighted contributions, thus obtained, into an over-all value—a number or some form of quality index. The resulting quality index for the one unit can be combined with the other (N−1) quality indexes in a group of N units to obtain an average quality index for the whole group.

As has been indicated, one of the primary purposes of quality rating is to enable us to compare current product quality with what we believe it should be—to enable us to determine whether it is "good," "satisfactory," at the "desired" or "aimed at level" (to use commonly employed terminology), or how, by how much, or how seriously it deviates therefrom. We require, hence, some standard of reference with which we can compare current quality. The standard may relate to an individual characteristic, to over-all quality of an item of product, to groups of similar products, or to aggregates of dissimilar products. As has been pointed out by Dr. Shewhart,[8] the standard should be expressed in terms which are meaningful, consistent with custom, enforceable, and sufficiently broad to allow rational interpretation under different circumstances. It should represent a value which results when the combined economy of production and use is as nearly optimized as our knowledge permits. A little reflection will indicate that, since circumstances of production and use are constantly changing, and since our knowledge of all pertinent economic factors is by no means precise, our standards will be subject to continual revision. The setting of economic standards of quality is decidedly not an exact science.

Having established the standard of quality for a particular product, we can then proceed to compare current product with this standard. We might consider each of the quality characteristics in a positive manner by assigning to it "merits," increasing the number of "merits" as the value of the characteristic gets closer to the desired or standard value. Or we can on the other hand—and this method has had a long and successful history—assign an increasing number of "demerits" as excursions from the desired value become larger. In either case, the number of "merits" or "demerits" to be assigned will be affected not only by the degree of departure from its own "standard" but also by the significance of the particular characteristic with respect to the over-all quality of the product.[11]

We can simplify our evaluation process tremendously if we can justify ourselves in making what, in some cases, may be gross approximations, if we can assume, for instance, that all units meeting the specified requirements are equivalent in quality. In this case, we can base our quality measure for a group of similar units on the proportion of units in the group which have one or more individual characteristics with values outside of the specification; in turn treating those units which are outside of specification either (1) as of equivalent poor quality or (2) as differing in degree of poor quality on the basis of the extent of their departure from specification. This procedure is not properly applicable—or at least by itself not adequate—in those many cases where the specification limits are not, by themselves, sufficient to insure an acceptable level of quality. The average value of cross-talk on loading coils, for example, must be well within the specified limits (which apply to the individual coil) to insure the required quality of transmission of the lines in which a number of the coils are to be used.

One rating method expresses the quality significance contributed by a particular characteristic (or product) in terms of its excursions from a standard value, the excursions being measured in multiples (t) of the standard deviation (σ) of the measured characteristic (or product quality). This has many practical advantages: it is simple to handle statistically, is acceptable to the shop people to whose product it is applied, and fulfills its major purpose—control of the product at the specified quality level. (This method of measuring the significance of the departures from the standard in terms of multiples of the standard deviation should not be confused with t_σ as associated with confidence limits).

Another technique employs an index expressed in terms of the ratio of actual demerits found in the product as compared with the number of demerits expected when the characteristic or product in question is at the standard level.

While much of the discussion has been, and must continue to be, concerned with the principles of quality weighting—since weighting is involved in the process of combining the effects of the various quality characteristics—we must never lose sight of the importance of the individual characteristic. In some circumstances, obviously in the case where quality rating is directly related to the purpose of process control, major attention will focus on a particular characteristic. New designs, redesigns of current products, field complaints, or excessive nonconformance often prompt such attention. The quality control engineer must, of course, be familiar with the status of each of the important characteristics, in any event, lest he be misled by over-all composited rates. This is a case where it is necessary to see the trees as well as the forest.

Over-All Product Quality Should Be Economically Maximized

The problem of product quality rating would be complex even if it were to be confined to the rating of individual product units and groups or "lots" of the same or very similar units. In the usual case, however, there must be provided, in addition, some means of evaluating and portraying the composite or over-all quality of heterogeneous products. For example, in the communication business, we are concerned with the quality of thermistors and clay conduit, aromatic spirits of ammonia and klystrons, telephone poles and central office systems, nitrogen gas and diesel engines, etc., etc.,—not in these particular combinations, of course, but individually and, together with many others, collectively—today, next month, and from year to year. Management needs some measurement symbol—a chart, an index, a number—which will indicate, relative to some standard of goodness or *economic soundness*, the quality of the aggregate output in a given production period; that is, some symbol which will best represent the combined effect of the individual variations in the quality of the several products.

The goal of each product is to provide customer satisfaction and, for most of the products with which we are concerned, customer satisfaction is measured in terms of service. The term "service" is used here in

the broad sense to include those factors, such as appearance, to which customer reactions are esthetically motivated. Whether it be a telephone or a washing machine, the customer looks for satisfactory performance over a reasonably long, trouble-free, period. He is equally interested in another factor—cost. It is a fair generalization to state that we can almost always improve service at the expense of added cost. In the final analysis, the customer, and thus the Supplier's management and his quality control engineer, are interested in maximizing the service per dollar ratio.

Under these circumstances, in the face of a lack of any absolute measure of quality, we are easily led to adopt the dollar value of the product as the common factor which will enable us to combine the otherwise often remotely related product qualities. This presupposes, of course, that the quality standards for the individual products will have themselves been set at levels which represent optimized quality per cost; where cost includes not only the research, development production, and marketing expense but the expense associated with installation, operation, maintenance, depreciation and obsolescence as well.

In theory then, and in practice—as closely as we are able, and are justified, to approach the theoretical—we establish for each product a standard of quality which represents an optimum economic level. In the Bell System, we compute an index of quality for each product by comparing the observed value with its standard. We derive an over-all product quality index by weighting the contribution of each product's quality index by the value of the product, averaging, and comparing the over-all average with an over-all standard.

I hasten to point out that I am well aware that some may take issue with the propriety of this combination on the basis of dollar value. A fuse which carries current well beyond its designed limits and thus fails to protect expensive equipment, or a lineman's weak safety strap which introduces a personal accident hazard, will, on a dollar weighting basis, have little effect on the over-all quality picture which covers large quantities and varieties of expensive product. Safeguards against such irregularities lies in anticipating their possible occurrence, and in the employment of acceptance criteria and procedures which will, to the extent practicable, obviate their presence in accepted product. The technique of quality evaluation —and its consequences—should be reflected in all facets of the quality control job, in the prescription of acceptance sampling plans, the disposition of nonconforming product, the revision of a manufacturing process, etc., etc.

Reference has been made here to quality standards which represent desired values for individual characteristics and for over-all quality, and to those which represent desired levels for aggregates of various products. Since each of these standards bears a close relationship to the design requirements, and to the production facilities available for implementing them, and since the design requirements and facilities change from time to time, the quality standards are not static. They represent a level of quality, in terms of the existing design, which it is desirable to maintain under existing circumstances. It is unsafe, therefore—actually it is often erroneous—to compare a product's quality rate in one period with its rate in a different period and assume that one gets thereby a reliable measure of the change in the product's "intrinsic excellence." What was considered to be a "good" automobile twenty years ago is quite different from its "good" counterpart of today. Also, the over-all quality standards for combinations of more than one type of product must vary from time to time as the individual product unit costs and output quantities vary.

Aside from these considerations, it must be appreciated that the pathway to quality rating is by no means straightforward or clearly marked. Each step is subject to error: error in measuring, error in assaying the capabilities of the production process, error in judging the relative importance of quality characteristics and their deviations, and so on. Indeed, the very uncertainty of the quality rating course, and the necessity for the continual correction of our movement, persuades us to use all the available talents of the professional guide, that the progress of our never-ending journey may keep us as near as possible to our intended destination.

It is doubtful that there exists any single rating system which, in whole or part, represents the best technique for all circumstances. Any system which sets out to depict over-all product quality as a point or a single value is subject to the shortcoming inherent in any average; i.e. the good hides the bad, or vice versa. The various techniques, herein referred to briefly, have at least the merit of successful use; they have all contributed to the control of quality at a suitable level.

As a matter of fact, it is not the intent of this article to describe or compare any specific methods employed in quality rating technology. Deliberately, they are discussed sparingly, sketchily, and only so far as clarity demands. The primary purpose of this article is rather to examine the principles underlying product quality evaluation; to indicate the technological, mathematical, and statistical complexity* inherent in the problem of designing and implementing any mature quality rating program; and thus to demonstrate the professional character of the people equipped to carry on such a program properly.

Scarcely any reference at all has been made to the primarily statistical aspects of the rating technique. When we reflect upon the fact that each of the quality characteristics with which we deal is a variable, that its value is uncertain, that the combinatorial techniques can be mathematically intricate, and that we wish to associate with the ultimate quality rates a degree of confidence which will have operational meaning, we can appreciate the statistical skills which are required. Indeed the technological difficulties inherent in sound product quality rating in both the engineering and statistical area are so profound as to account for the source of my impression that—of all phases of quality control—the formalized process of quality evaluation is farthest from its ultimate maturity.

When the chips are down, the best single picture of the over-all quality of any product derives from the judgment, perforce qualitative, of the individual qual-

*I am indebted to my colleague, R. B. Murphy for the following gustatory metaphor which I quote with his permission: "It seems to me the most profound complexity is trying to preserve a rational relation between the real world and the quality evaluation technique. This problem is an odd gumbo of technical, economic, and psychological vegetables. The job is nevertheless necessary, and my feeling is that to determine whether the ingredients have been properly combined and seasoned can be done only by continuous tasting—to see whether in the long run we have created a "fair impression" that has led to "fair results," and this is a matter which must depend not only on our knowledge of the technical situations which existed and contributed to the evaluation but the manner in which these data were compressed in the evaluation and the result of such compression on the reading public and the people whom the reading public affect in turn."[12]

ity control engineer within whose responsibility the particular product lies. His judgement is supported by the quantitative information afforded by formalized rates, but it must be tempered by information from such sources as quality surveys and engineering complaints, which presently find little application in the formalized rating process. So it is, then, that an over-all "Quality Report" should include not only the quantitative information depicting individual characteristics, products, and over-all output, but also supplementary qualitative and interpretive statements which are based on the quality control engineer's knowledge derived from sources which are not, nor likely to be, amenable to rigorous statistical treatment.

Engineering vs. Statistics

It should be clear from what has been said that product quality rating presupposes the exercise of a high degree of expertise in two fields, broadly characterized as engineering and statistics. The necessary combined knowledge may be found in the one individual. But especially as the quality control job takes on more maturity, as it demands original thinking of a professional character rather than mere utilization of an already routinized procedure, there is likely to appear a specialization in each of the two broad fields. This does not mean that the one specialist will be unfamiliar with the other's primary forte. Actually, to insure the necessary degree of cooperative effort, there must exist a substantial over-lapping in proficiency as well as in sympathy.* Even within the engineering field of quality control, as the employment advertisements bear witness, a degree of specialization is advantageous if not actually necessary. The mechanical engineer, *per se*, would be expected to find himself more at home with the quality engineering aspects of automotive gear than with those of the guidance section of a missile. At least at Bell Laboratories, we found it necessary, as anticipated in the article by Dr. Jones, to provide ourselves with "Quality Specialists" in the sciences and engineering as well as with specialists in mathematical statistics.

If "quality is everybody's business," as it should be, there must be some distinguishing characteristic attributable uniquely to "quality control" to justify its continued existence. This characteristic, the author believes, is to be found in its "over-all," detached, objective approach to quality, to the end that the integrated individual quality responsibilities of design, production, and use are, as closely as possible, economically optimized. Thus quality control in its most widely used industrial applications involves (1) the ability to recognize, measure, and evaluate the quality aspects of design, production, and use, i.e., engineering, and (2) the ability to recognize, measure and evaluate the significance of relationships, i.e., statistics. Quality Control was born as a result of the marriage of these two. It is highly probable that a technological expert other than an engineer might properly replace the latter. The statistician—or his equivalently informed counterpart—must always be available despite the fact that, as a professional, and as a statistician, he may not be qualified for engineering license.

*This necessary close cooperative relationship is excellently espoused and illustrated in an article "The Relation Between The Engineer And The Statistician" by Joseph Mandelson—Industrial Quality Control Vol. XIII, No. 11, May, 1957. Incidentally, on the occasion of an address before the Army Chemical Center, Md. several years ago, I was surprised and pleased to learn that their underlying philosophy, as well as many of the details of their organizational set-up and practice of Quality Assurance closely paralleled those of Bell Telephone Laboratories.

Significant contributions to the field of quality control have been and will continue to be made by professionals of many types. The Society must be careful, in its endeavor to advance its recognition as professional, not to jeopardize the status of those members of the highest competence who might not qualify specifically as professional engineers. In particular, it must not segregate those respected members—the professors, who, in the event, do not need additional testimonial to their professionalism. I cannot forget that my first consciousness of the type of thinking which underlay the development of what is now known as quality control occurred many years ago, when, as a student in electrical engineering, I was exposed to a course in "Precision of Measurements" taught by a professor of physics!

Summary

The underlying purpose of this series of papers is to disclose the professional aspects of the activity referred to as Quality Control. There exists a wide variety of concepts as to the scope of this activity—its responsibilities, its *modus operandi*—and there exists, in consequence, some uncertainty as to the necessary qualifications for its practitioners. In these circumstances, I have felt it apropos and timely to preface my text on product evaluation with some history concerning the introduction of a quality control activity which has been carried on as an independent function by a group of professionals continuously over a period of thirty-five years. The manner and substance of the presentation should make it apparent that my opinions and convictions are deeply and indelibly colored by my experience in one industry—the Bell System. In fact, I have used the term "Quality Control" herein in the same sense as "Quality Assurance" as practiced by Bell Telephone Laboratories.

It was not necessary to "sell" quality control to Bell Laboratories' management. Management conceived the activity, directed that it be developed and prosecuted, assigned the professionally qualified people to do the work, gave them status as full partners in an over-all development and research organization, and provided them the authority necessary to the success of the operation. From such a propitious genesis—nurtured by the whole Bell System's continuing keen interest in quality, from raw material to ultimate communication service—one might anticipate a program of lasting fertility. Whatever success it has attained is due in large measure to the steadfast support and encouragement which it has received from management.

It is appreciated that the particular organizational set-up of the Bell System is especially favorable to an adequate over-all quality control program. The objective of the entire System is to provide the best communication service consistent with its cost. This is the guiding directive of the parent American Telephone and Telegraph Company. This is the purpose of the research and development activities of Bell Laboratories, of the purchasing, production, installation and repair activities of the Western Electric Company, and of the several telephone operating companies which require presently almost two billion dollars' worth of additional communication product annually to implement this purpose. Despite the designer's natural pride of creativeness, the producer's pride of his skill in manufacture, and the operator's pride in his utilization know-how, each is willing to subordinate his individual prerogatives in the interest of maximizing

over-all economic quality. This close community of endeavor provides an unusually favorable atmosphere for a completely integrated quality control program. I recognize that the practice of quality control is not always carried on under these congenial circumstances, which so greatly simplify the implementation of quality controlling decisions. This deficiency does not impeach the validity of the principles of quality control engineering; it merely makes their effective application more difficult.

Quality control represents an over-all program comprising a number of closely integrated functions. It may be compartmentized only for the purpose of analysis and ease of description. One of the functions, one which courses continuously through the whole control system, is product quality evaluation—more specifically, what has been referred to here as quality rating. Successful quality rating presupposes a mature knowledge of the quality aspects of design, production, and use, and the exercise of the professional talents commonly associated with the terms "engineering" and "statistics." Proper execution of the other functions of quality control requires knowledge of the same level and nature. It is my belief—and, at least in the Bell System, long experience has demonstrated it to be true—that specialization should, except perhaps in the statistical area, be on a product basis rather than on function.

By citing the fact that Quality Control was conceived as a new branch of engineering, was staffed by an organization predominant in engineers, and requires for its functioning the type of knowledge commonly referred to as engineering, I do not intend to imply a secondary importance to the statistical aspects of the job. Quite the contrary! No one is better aware than I that this new "branch of engineering" originated from melding these two fields of art and science. In my long experience, I have yet to see a difficult problem in the application of quality control properly solved without the contributions of both the primarily engineer and the primarily statistician. Indeed the success of the whole quality control program depends upon the ability of the quality control engineer to search out and amalgamate knowledge and help from each of the sources whence ultimate quality traces its growth.

A society is a professional society if its members are in fact professional, whether or not they be legally licensed as such. If the quality control program is carried on, as it should be, at the professional level, then its practitioners must, *ipso facto*, be professionals. On the other hand, a job's stature is determined largely by the caliber of those assigned to it. There arises, thus, an enigma akin to that posed by the question concerning the antecedent priority of the hen and the egg, and likely of about equivalent significance. The point is that the Society should so define the technique of quality control as to necessitate full professional qualifications for its exercise. "By their fruits ye shall know them."

While attention has been drawn frequently here to those personal attributes which are primarily associated with, or are of importance to, the more purely technical aspects of the quality control job, scarcely even allusion has been made to those which fall under the broad classification of ethics, those which determine what the layman associates with a person's "character." It is difficult to visualize a legitimate pursuit which will not benefit from any of the ethically desirable traits in its personnel. Quality control is decidedly no exception. Since in the normal course of his duties, however, the quality control engineer must call attention to, if not actually stigmatize, the results of others' shortcomings, and since he must pointedly, although constructively "needle," he must be completely and honestly objective; he must act, unvaryingly and convincingly, in a manner which attests to his unquestioned integrity. Thus motivated, his honest errors will be excused, his pestiferousness tolerated, and he will have the key to the warehouse of cooperation from which he must draw in such abundance. The aforementioned "well spent, sober boyhood" is certainly conducive to such attainment, though it may not actually constitute what the lawyers term a "condition precedent."

Acknowledgments

I wish to express my appreciation for the constructive comments and suggestions of my colleagues, C. E. Fisher, G. R. Gause, R. C. Koernig, R. B. Murphy and Miss M. N. Torrey concerning the first draft of this article. These are the people who actually see to it that the difficult job of quality rating is properly carried on for the Bell System.

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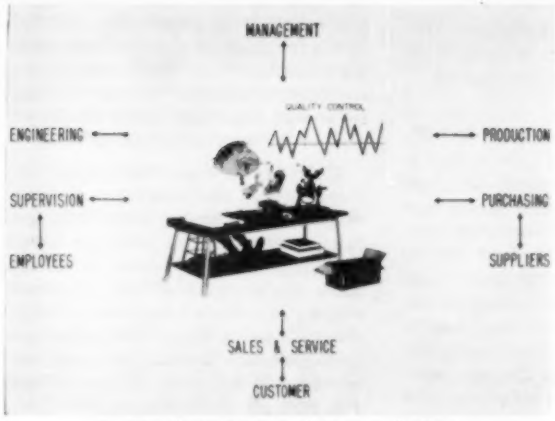
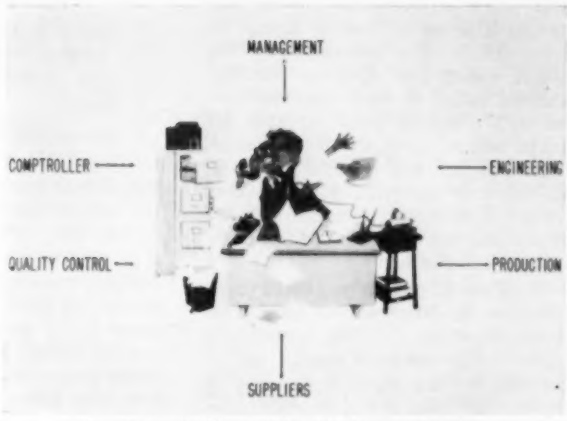


Quality Control Lines of Communication

The data, analyses and calls for action generated by Quality Control must reach a wide variety of people. Each recipient looks at Quality's message from his individual viewpoint. His background of experience, the problems of his particular position in the company influence his reaction. The approach that goes over with one may may fall flat with another.



Purchasing's View of Quality Communication

Each man that Quality Control wants to reach, such as the buyer in Purchasing, is bombarded from all sides by incoming communication. The Comptroller is after him on cost of materials, Production beats him for holding up schedule, Engineering confuses him with technical problems, and so it goes. Quality's message faces stiff competition for attention.

Communicating Quality Control Ideas

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Modern Quality Control has offered industry a better way to control manufactured product and a challenge to improve management efficiency. A wide variety of techniques are available. Interesting new ones come along each year. In fact technique has advanced more rapidly than the application of methods that are already available. Few companies can state honestly that they make full use of the quality control techniques that have been widely published and taught ever since the nation-wide training programs during World War II.

Why is this true? What is holding back the general acceptance of methods that have proved to be extremely profitable in many applications? Whenever Quality Control specialists get together, you hear this question being asked. The comments that follow often reveal a feeling of frustration. "They" are holding us back—"they" referring to management or purchasing or tool engineering or sales or whoever. These people just cannot seem to appreciate how much the quality control man has to offer. Now we might just decide that Quality Control people are more advanced and more open minded than the people with whom they must deal. This comforting conclusion does not help us to put across new methods. It will not increase the stature of quality control in a company. We must dig a little deeper.

A clue to the cause of the problem may come from examining one fact about the nature of Quality Control. We do not produce anything. The essential core of industry consists of men, materials and machines. From these three come the product that is the company's bread and butter. The rest of the organization can only service this core. A service such as purchasing buys material that comes in the door and is used. Tool engineers

ASQC LCS Code 340:10:000

Presented at the 1957 and 1958 sessions of The Statistical Methods in Industry Course, University of California, Los Angeles, Calif.

develop machinery to get the job done. The sales people bring in new orders. The janitors keep the plant clean. But Quality Control cannot point to such tangible results. We cut no metal, tighten no nuts, weave no cloth. We stand at one side of the main stream of productive activity, judging and criticizing other peoples' efforts. This does not lead to winning popularity contests.

You may properly object that modern Quality Control does a lot more than criticize. By systematic analysis it uncovers useful information in the confusing mass of industrial data. It can measure the inherent variability of manufacturing processes to reduce wasted effort. We can even predict troubles before they happen, and design controls for processes that will keep them in line. These are commendable skills, but let us ask what is the necessary result of our charts and analyses and predictions. It is that somebody else, not Quality Control, must stir himself to do something. Engineering must change design. The tool room must rework a die. Purchasing must get after a supplier.

So we see that Quality Control depends on getting other people to act on the information it provides. This is not said in criticism. After all, management is defined as the art of getting things done through people.[1] Quality Control then is one form of management—management staff, more accurately—because we cannot give orders to the departments whose action we desire.

Getting things done through people necessarily involves communicating with them. They must receive some message from Quality Control—one that they accept and that will move them to act. The key word is "accept". Until a communication has been accepted it is useless. It may even have done positive harm. Of course a Quality Control man is not going to put out a communication that is not acceptable from his viewpoint. The problem must be at the receiving end. To understand why there is a problem we might consider some ideas on communication in industry expounded by men like Dr. Tannenbaum of UCLA and Dr. Brighouse of Occidental College. The general principles they develop can be applied to the particular circumstances of quality control.

Types of Communication

To begin with, Dr. Brighouse divides communications into some of the types of messages conveyed.

1. Facts
2. Explanation — why, what do the facts mean?
3. Emotion — how do we feel about the facts or about the people with whom we are communicating?

Fact messages are the most straightforward. They result in the most rapid feedback. Suppose a weekly report says that the sheet metal shop produced six per cent defective parts. This is a fact. If the superintendent of that shop thinks our facts are wrong, the feedback will be rapid and emphatic. Because of the rapidity of feedback, we generally try to get the facts straight.

For the other types of message—explanation and emotion—feedback is less certain and sometimes missing altogether. Of course, modern quality control believes strongly in searching for the explanation and in communicating this to the people who can act to correct problems. If an assembly is failing in test, why is this happening? Facts reported without regard for explanations can lead to trouble. For example:

Quality Report: A die set is turning out too many bad parts.

Explanation: The tool engineer could not get a better die built in time to meet the start of production. He already has an improved design in the mill.

If there are too many such reports, particularly if the reports cause the tool engineer's boss to demand time consuming answers, Quality Control's communications will soon be greeted with annoyance rather than acceptance.

Explanations have a way of leading us into the third type of communication—emotion. Quality Control often gets into one of those corrective action meetings called to hash over the causes of rejections. What emotional messages do we send out along with the impersonal facts and explanations? That the designer was pretty stupid? That the purchasing agent should stop giving business to his brother-in-law? That the shop foreman could train his people properly if he just wasn't so lazy? Or that the production expediter should drop dead? We may not mean to convey these emotions, but our tone of voice, our expression, our reaction to a foreman's recital of his troubles all put the emotional messages across. We humans are so constructed that we do not like to accept messages from those we feel to be unfriendly or critical.

Even if we make sure that our story is true and complete, and we take care to avoid emotional pit falls, this does not seem to solve all problems. Dr. Tannenbaum has some suggestions as to why successful communication is more difficult than we think it ought to be. One problem is that the receivers we use to hear the other fellow are not Hi Fi instruments. They have built in filters and distortions. Our preconceptions accumulate and our opinions harden so that we cannot react freely to a given stimulus.

Conflicting Viewpoints

A loyal Brooklynite has a hard time accepting the message that the Dodgers would be better off in Los Angeles. Whether impartial judgment supports the move will make little difference. A shop foreman is long conditioned to the idea that he is doing all right until inspection finds some parts that are outside of tolerance. The control chart method runs head on into this preconception. In 1945 the writer set out to install statistical methods in a large machine shop. Some of the reactions are still vivid in memory. Take the effort to install $\bar{X}$ and R Control Charts and see how it appeared to the people involved:

Quality Control Engineer—Control charts provide a more systematic method of checking machine output. Rework and scrap will be reduced. Tool resetting and replacement will be on a scientific basis rather than by hunch or after trouble starts.

Machine Operator—The new procedure interferes with his right to use his skill and experience in running the machine. The Quality Engineer is questioning his ability to set the tools properly.

Shop Foreman—The charts result in shutting down the machine for no good reason. Production will drop.

Floor Inspector—The added paperwork is a nuisance. His job is being degraded because some lines on a chart replace his judgment as to whether the machines are running OK.

Shop Steward—This is another attempt by management to put unreasonable controls on the workers. Besides, the inspector is being required to keep records and make calculations that are not in his job description.

Thus a project which was obviously a good one to the quality engineer appeared in quite a different light to other people. It is not that they were less intelligent or less willing to accept a new idea than the rest of us. The attitudes and emotions with which each man reacted had been set by his past experience. His receiver was tuned to a different frequency.

One of the most important attitudes each of us carries about is the way we think of ourselves. This is our self-concept, and it is very important to our sense of security. Any communication requiring a change in that self-concept is felt as a threat. Logic and reason might deny that any threat is involved, but our feelings do not work by logic and reason. When a new idea raises questions about our self-concept, our defenses go to work. The result is that we cannot hear what is said. We rationalize or explain away information to make it more acceptable or we accept only things that are consistent with our self-concept.

This helps to explain the floor inspector's reaction to the control chart. He was an experienced man and proud of his skill with vernier calipers, depth micrometers and dividing heads. His self-concept included the belief that he could ride herd on a group of machines and operators and keep them in line. Now along came this bright boy of a quality engineer with talk about upper and lower control limits and process averages. Something he did not know about. Suddenly the inspector's position in the shop was not quite as secure as before. He was faced with the need to change his self-concept, and his first reaction was defensive.

How about the tool engineer mentioned earlier. Any good tool engineer is sure his new die is the best yet. His self esteem rests on the belief he can design better tools than anybody. Quality comes out with a process capability report that the tool can be expected to turn out 2.5 percent defective parts. Does this fact fit in with the tool engineer's self-concept? What will his reaction be? If he is as human as you or I, he will start by being mad at Quality for trying to make him look bad. Next he will blame the defectives on careless operators or the incompetent who set the die in the machine or the engineer who puts tight tolerances on dimensions that do not mean anything. In other words, he will defend himself against the threat to his self-concept that he is a top tool designer. If QC's object in putting out the report was to get the tool design changed, our communication has been unsuccessful.

Let us put the shoe on the other foot. We who are in Quality Control are apt to feel that we are the essential guardians of the company's reputation and integrity. Things will soon go on the rocks if we are not constantly checking every operation. Then one day the boss says that overhead costs are too high. Quality Control has too many people. What is our reaction to this message? Can we think impartially of the boss' problems in meeting competition; the fact that the board of directors has been riding him about the overhead rate? Or do our defenses go up in a hurry? The size of our department is vital to our self-concept of importance in the organization. Our sense of security is threatened.

Communication Skills

You can see the point of these examples. Communications, verbal or written, sent on their way with the best of intentions, run into an astonishing number of problems. People react in ways that are, from our viewpoint, unexpected and unfortunate. It looks as though Quality Control should add skill in communication to its mastery of statistical method. Communication is classed among the human skills rather than with technical skills by Robert Katz in an article in the *Harvard Business Review*.[2] He points out that anyone who desires to climb the administrative ladder will find human skills more important with each upward step, while technical skills become less vital. The subject cannot be covered fully in a paper such as this. Two basic principles emphasized in management training are a start in the right direction:

1. Understand and make room for the other fellow's point of view.
2. Use the full potential of each person you must contact.

Understanding involves the difficult art of listening, letting the other fellow develop his side of the story, accepting his problems as just as genuine to him as ours are to us. Perhaps we are certain that our view or plan is the best. From a communications viewpoint this does not cut any ice. We are asking for understanding and acceptance. We will get it only to the extent that we are able to give it.

Understanding prevents errors in our approach. A feeling for the purchasing agent's view of the world will keep us from asking him to get excited over a report that says Vendor B's product is more than three sigma below standard according to the Student's t test for significance. We may be pleased with ourselves for knowing how to use Student's t, but this will be the only message we get across.

Listening opens a path for feedback. This is important. Interesting tests were tried under controlled conditions. A series of instructions were given with and without feedback; that is, the opportunity to question the instructor. Without feedback, two things

Chemical Division Course

A course in the "Evaluation and Interpretation of Physical and Chemical Testing Methods," will be sponsored by the ASQC Chemical Division in Philadelphia, Pa., May 19-21.

Instructors will be Grant Wernimont, Eastman Kodak Co., and John Mandel, National Bureau of Standards.

Topics covered will include measurements—the data and the process, development and evaluation of the measurement process, estimating the uncertainty of measurements, comparison of different measuring processes, interlaboratory evaluations, and the association between different types of measurements.

Within this general framework will be discussions of control chart techniques, factorial experiments, precision and accuracy, statistics of the straight line, sampling of materials, sensitivity (the comparison of methods), point and interval estimation, and inter-laboratory testing.

For additional information, see "Clinics, Conferences and Courses," page 39, this issue.

happened: (1) the instructions were not executed as well; (2) the people on the receiving end were annoyed at the instructor for doing a poor job of communicating. This result suggests a danger in too much reliance on written reports and charts. These are a necessary part of our job. They cannot substitute for the give and take of personal contact. It is feedback that tells us how our communication is received.

Feedback is also important to the second principle, that of using the full potential of those we must contact. As was pointed out before, Quality Control depends on the interest and action of other people. Each project is a group endeavor. Charles Bicking has pointed out the advantages of the team approach to quality projects.[3]

If anything useful is to result, the team members will have to adjust to a new approach. They must endure the unwelcome process of changing established habits. Writers on industrial psychology, like Douglas McGregor[4] and Thomas Gordon[5] have suggested that the process of change is greatly aided if each member of the group feels like a full partner. He wants the freedom to criticize and question. He must be safe in offering an idea of his own without risking ridicule by superiors or by "experts", quality or otherwise. Only in this atmosphere does the group member become an active participant. When someone from outside tells us how to do our job better, we feel pushed around and defensive. When we can be part of the study and planning and goal-setting for a project, we will be in there pitching.

Looked at in this light, the fascinating bag of technical tricks developed by Quality Control may be a danger. We fall into believing that we are better equipped to determine the nature of an industrial problem than the man who struggles with it every day. Perhaps our bag of tricks should be left on the shelf while we find out what is really eating the purchasing or shop or engineering man. What are the limits on time, money or manpower with which he must struggle? What objectives does he see as practical and desirable?

If this mutual exploration can be carried out by the group involved, with the quality man listening rather than selling, something very helpful can happen. Some needs and objectives will be found that have the active support of the group. Then the quality engineer can apply the knowledge and techniques he has available. His contribution takes its place with the contributions from the rest of the group. He has the great advantage that the others see his contribution as something that helps them toward their own objectives. When each member puts his energy and skill into achieving a group goal, progress is remarkable compared with when the same people work along separate lines. When the pioneer communities in America united in a house-raising bee, the chips flew much faster than when the same people worked alone.

Change Requires Time

The objection will be raised that these principles are time consuming. Pressure is characteristic of American industry. Who has time for patient listening and encouraging each individual's participation? The answer may be that in attempting short cuts in the name of speed we defeat our own purposes. In the summer of 1954 Quality Control in my company picked up a promising idea from the automotive industry. It was a new approach to vendor-vendee relations in our drive to achieve higher quality in purchased parts. We set out to apply the idea. A year later we were still struggling to get started. It was the end of 1956 before we could point to solid results in money saved and quality improved. Why did it take so long? It was not technical difficulties. It was the problem of communication. The purchasing people were afraid of the effect on cost and delivery. Our engineers doubted that the program could provide adequate coverage. The vendor's engineers quite reasonably wanted a hand in specifying tests. The necessary records were a problem in receiving inspection. Whenever we tried to move forward without first understanding the other fellow's point of view, we were thrown for a loss. The project got rolling only when the people involved accepted it as a personal objective. It is worth adding that the approach originally proposed by Quality Control changed and improved many times as these people made their contributions.

You have probably heard the remark, "We will never have a strong Quality Control program in XYZ company until somebody is given real authority." What the speaker is longing for is authority to make those knuckleheads he deals with accept his ideas whether they like them or not. There are two major fallacies in the idea. One is that a general management can no more allow quality to dominate over schedule and cost considerations than they can afford to let quality get shoved aside. The other is that authority used to force acceptance of an idea is a trap. A boss can make his subordinates fall in line, but only at the cost of accumulated feelings of resentment, insecurity and lack of understanding. Each issue forced robs the boss of a measure of the willing cooperation that he needs badly.

In the beginning we asked the question, "Why is it that the techniques of Quality Control seem to have advanced faster than the application of those already available?" The answer may be that in concentrating on scientific technique we have been neglecting a more difficult side of our jobs—the art of communication. For successful communication no set formula exists. The pat answers of "salesmanship" will not carry us very far. An honest effort to understand industrial problems from the other fellow's point of view, an approach that puts a high value on his contributions; these may offer the surest road to our own objective—the widespread acceptance of the many advantages offered by modern Quality Control.

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Floor Control of Assembly Quality

A Practical Approach

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MUCH has been said and written about using various statistical methods available for evaluating significant quality levels and trends. It has been the writers' experience that simplicity of administration and ease of understanding must characterize a successful program for a quality control system.

No matter how well conceived a new or changed method may be, the tried and true statistical quality control techniques are frequently found to be the best for a large scale assembling and testing production program. This article shows how one of the old stand-bys has been applied to pinpoint an operation at the first sign of trouble. It is written from the viewpoint of the man on the floor with emphasis on the operating details.

This familiar tool is the control chart for defects, commonly known as the "c" chart. Operationally, the inspector merely plots the total number of defects observed. Details of "c" chart plotting are given in the Appendix.

The use of control charts for defects is particularly advantageous for inspection of complex assemblies. The technique used is to employ such control charts at sequential inspection operations so that the chart covers only a particular segment of the build-up of a unit. This is normally accomplished by simply following production planning—the "flow" chart—and deciding at which inspection operations controlled quality is important. Control limits furnish the means of knowing which particular units signed off by individual production operators show an excess over normally expected defect quantities. Figure 1 illustrates the "c" chart design developed by the writers.

ASQC LCS Code 112:70:400

These charts are clearly displayed at the inspection stations. This is not only informative but is good practical psychology as well. It can be disconcerting to a production line foreman to observe touring top level company management taking notice of a particular control chart that is showing an out-of-control defect level. Competition is a healthy thing.

Before these charts were initiated, production and quality supervision depended upon regular weekly and monthly reports to indicate quality part histories in the various assembly areas. In these reports, details of defect types, acceptance rates, summaries, cross-indexes, and the usual assortment of defect analyses provide a picture of what *had* happened to a particular unit. Most such reports were not completely timely. A week's lapse between the occurrence of a defect and the defect's appearance in a report was not unusual.

The "c" charts provided operating production and quality supervision with immediate indications of trouble spots. These charts were not used for product acceptance purposes but as a statistical aid. Unit quality acceptance was determined by inspection performed according to authorized sampling plans (or 100 percent inspection).

At the outset of this program, a single assembly line was chosen on a three-week trial basis; "c" charts were set up at a sub-assembly, in-process, and final inspection operation. Not more than six production operators' work was covered by one chart. After the inspector had plotted defect totals for a week, the average defects-per-unit (ADU) was computed. An upper control limit was marked on a new "c" chart.

This weekly control limit was based upon the formula:

$$\text{ADU} + 3\sqrt{\text{ADU}}$$

This system was then expanded to cover all assembly inspection operations after the trial run was complete and "bugs" eliminated. After several months of chart usage, it was agreed by those concerned that a selected period of time would be used as a base from which all future production defect levels would be measured. This period of time was a single month for which a control limit was computed based upon the overall grand average defects-per-unit for that month. This control limit became the "action" limit. The weekly control limit for each chart was still re-computed based upon that week's average defects-per-unit, but this weekly control limit was now set according to the formula:

$$\text{ADU} + 2\sqrt{\text{ADU}}$$

This tighter limit resulted in more indications of lack of control, hence more investigations by production supervision. However, increased effort by operating production supervision resulted in greater uniformity among operators and still lower defect levels. It was agreed that the "action" limit would not be relaxed without extreme justification, such as a major product change. It was further agreed that the "action" limit could be tightened if workmanship quality improved over a consecutive four-week period. Consequently, monthly review of "action" limit settings was maintained.

Each week the control charts were picked up and analyzed. The control limit was computed and entered on a new chart on the spot. If the control limit was found to be equal to or greater than the "action" limit, production supervision was notified in writing. A week's probation was given to permit production to investigate and obtain corrective action. However, if at the end of the following week, the control limits when recomputed were still found to be equal to or greater than the "action" limit, Quality suspended further acceptance from the operations covered by that particular chart until a real "fix" was evidenced.

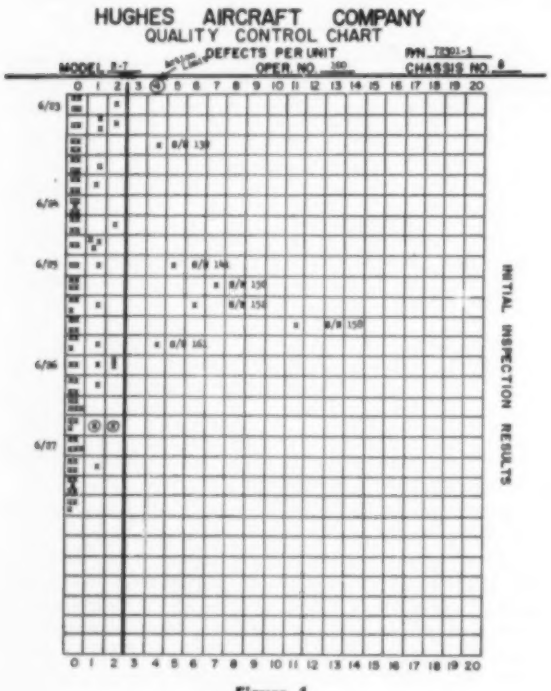

Figure 1

Considerable competition became very apparent among the various assembly operators and their supervision. Production supervision maintained regular and frequent review of these charts. A single glance informed them if defect levels or trends were becoming a problem. Figure 1 shows how a sudden deterioration of product quality occurred during the middle of the week. Prompt investigation by production supervision showed that a new production operator was having difficulty in following the assembly planning sequence. Special instructions to this operator resulted in immediate improvement in quality levels by the following day.

These charts DO work. Results have been as startling as all the usual claims made for statistical quality control. Such success may interest other companies in following the simple instructions given below for utilizing these modified "c" charts.

Appendix

Instructions for Plotting Defects-Per-Unit Charts

1. Write in the model type, operation number, and chassis number. The operation number refers to the inspection operation covering the output of production back to the previous inspection.
2. Only the total quantity of defects observed per chassis will be plotted on the chart, using the symbol "X". If no defects are noted, enter an "X" in the zero column.
3. The results of the initial inspection only will be plotted. Rework squawks will *not* be plotted, since the object of the chart is to appraise current chassis quality as submitted to inspection from the normal production process, not the rework process.
4. The results of five (5) chassis inspections will be plotted on each horizontal line to permit rapid visual determination of process defect levels.
5. A control limit will be calculated and entered on the charts in red pencil by a quality engineer. This limit will be designated upper control limit (UCL). If the number of defects noted on any one chassis exceeds the upper control limit, plot the total and record to it the manufacturing serial number of the chassis. Any out-of-control units will be held by the inspector pending production supervision's review of the quality paperwork accompanying the chassis.
6. At the left hand side of the chart grid, note the date of the inspection opposite the first horizontal line beginning the day's inspection. For example, in Figure 1, 25 chassis were inspected on 6-23; 15 on 6-24, etc.
7. If at the end of the shift, a group of five (5) chassis are not available for completion of the five-group plotting, on the following shift place a circle around those "X" plots needed to complete the five-plots-per-line grouping, as shown in Fig. 1 for 6-26.
8. These charts will be turned in weekly to the area quality assistant foreman.
9. These charts should be clearly displayed at the inspection station so as to enable affected personnel to determine quality trends and problems quickly.

Weapon Systems

RELIABILITY

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Introduction

In this article I shall discuss weapon system reliability and indicate some of the trends in weapon system programs and some of the implications for reliability in these trends.

An aspect of the reliability problem I want to discuss in some detail is that of specifying quantitative requirements for reliability which are both meaningful and realistic. I would like to make a few suggestions as to how this problem might be approached in practice and comment on some of the contractual aspects as well.

Trends and Factors to be Considered

Some of the most significant changes in Air Force weapon system programs in recent years are the result of the application of a systems concept of management. Perhaps I should turn that around and state that major changes in performance, effectiveness, and employment of modern weapons, the extreme environments and above all, the fantastically increased complexity of modern weapon systems have required the application of broader management concepts to these systems.

This approach we refer to as the "weapon system concept." This is a management concept for planning, scheduling, and controlling — from inception to successful introduction into the active inventory as an operating entity — the complete weapon system; i.e., the air vehicle, all of its component elements, its supporting equipment, and all effort needed to prepare it for active employment. Air Force-Industry application of this concept has, we believe, achieved successes not possible without recognition of the need for and application of the concept.

Since its development there have been extensions of the system concept. With the advent of complex ground electronic supporting systems used with both missile and manned aircraft systems, we recognize an order of systems larger and more fundamental than what we call a weapon system. The combination of several interrelated weapon systems and supporting systems together comprise a still larger system we might refer to as a "mission system." These extensions of the systems concept have brought about certain changes in the organizational structure and procedures of Air Research and Development Center and will undoubtedly bring about others.

In applying the weapon system management concept the Air Force has chosen to delegate greater engineering responsibility to weapon system, subsystem, and equipment contractors. With delegation of increased engineering responsibilities there is need to decrease specification-imposed detail design demands which can shackle a contractor in performance of his responsibilities. Specifications and related documents have been published and others are in preparation which should improve our procedures for describing the data we really need—and what we will no longer require—for approval of contractor developed materiel. A clear distinction is made between data which must be submitted to insure the contractor's course of action is satisfactory, and data which is prepared and retained by the contractor and provided when requested. In general, this means that contractors will account to the Air Force for achieving the required performance of larger elements of the system—not the component parts. The contractor will have to insure that the components are in themselves adequate and be in a position to provide data that verifies this at the request of the Air Force.

We might note in passing that the weapon system concept does not mean that the Air Force abrogates its responsibilities to industry. It does recognize the capabilities of industry and delegates certain specific responsibilities, retaining the prerogatives of a senior partner and a customer.

A major factor in the reliability picture is that we buy services and materiel with dollars, and we buy competitively. We

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try to obtain maximum quality for least dollars by competitive bidding and proper evaluation of proposals. In this process, any design factor not treated quantitatively will tend to take second place to such factors as performance; budget and scheduling considerations tend to overrule technical considerations. The effect seems to be a strong tendency to budget and to bid unrealistically with respect to such factors as reliability. The facts of life are, however, that we eventually have to pay the price for quality with added dollars and worse, added time. It must be recognized that a sound common basis, including reliability goals, must be used for estimating costs, competitive bidding, and evaluating proposals.

We have indicated some of the trends in weapon system programs including delegation of greater responsibilities and freedom in design detail to industry. With greater freedom as to the "how," there must be complete understanding as to "what" is required; i.e., more clearly defined requirements. These requirements must, of course, be meaningful in the context of higher-order systems. In addition, a sound basis for estimating costs, competitive bidding, and evaluating proposals all require clearly defined goals. I submit that establishing meaningful and realistic reliability requirements is basic to a sound approach to reliability.

The role of management in this picture is vital. Management responsibilities include establishing goals, providing direction and control, and supporting the many activities which together comprise the necessary reliability effort. Without question, the first problem for management is to determine what reliability we need. It has been stated in a recent paper[1] that the expenditure of millions of dollars e i t h e r without this knowledge or because of the lack of it, is a step toward economic and perhaps military suicide.

Reliability Requirements

With regard to definition of quantitative requirements there is a school of thought which says that any requirement is better than none. While I have to agree with the thought, I think we can do much better than that. The problem is difficult, but it is possible to describe some of the things which must be considered and indicate a general approach to the problem. What I have to say here will, I hope, highlight some of the problems as well as indicate approach. These remarks apply specifically to systems intended for the operational inventory at a given time.

From the definition of reliability,* it is clear that specification of reliability includes definition of the article, the function(s) to be performed, the operating environments, and the time of operation, as well as the required reliability. Most of these factors are derived from the operational problem and the nature of the system. They are implicit in a statement of mission to be performed and the techniques employed to do the job.

The number representing reliability must be both meaningful and realistic. It must be meaningful in the systems context; i.e., as a combination of design factors representing military worth and as a combination of system elements. By realistic I mean simply-achievable in some given time.

It has long been the practice to refer to something we call design objectives. Design objectives are not always regarded as a contractual requirement and as a result are not always as realistic as they should be for a system intended for operational use at a given time. If they are not realistic, they have no chance of becoming true contractual requirements since their achievement cannot be demonstrated.

I suggest that we need both a design objective and minimum acceptable values for reliability. Our design objective should be an optimum weapon system; i.e., one which provides the most effective balance between all design factors for least total cost to the nation. Minimum acceptable values for reliability should define a usable system—and I mean something quite specific by the term "usable system." A usable system is one available at the time required which will provide the required military capability and can be maintained and supported. Its use may well involve certain brute force effort, perhaps in maintenance, so that it could not be called an optimum system. Nevertheless, with a usable system, we have the required military capability when we need it.

To insure that we achieve usable systems, criteria must be defined and established which permit producer and user to agree on acceptable figures. To establish definitive criteria, requirements must be broken down into terms which are meaningful to the user; i.e., the operational c o m m a n d s , and which permit quantitative treatment. It also helps if the kind of terms are easily visualized so that judgment can be exercised. Another way of describing the kind of numbers we want is to say that we want negotiable numbers—negotiable with the operating commands to insure that they define a usable system, with the contractor to insure that they are achievable.

Reliability (essentially the probability of success) of a weapon system might be broken down into such factors as:

a. Flight reliability
b. Launch rate
c. Reaction time
d. In-commission rate
e. Turn-around time
f. Storage reliability
g. Percentage up-time, etc.

Obviously we do break success down in this fashion. In practice, however, we have not always identified and defined all such terms early enough in a program. If we do not specify them early enough, we are in danger of building systems and then finding out how good (or bad) they are in these respects, rather than taking positive steps to insure that these requirements are reflected in the design.

Early program planning documents will specify some of these factors but not necessarily all. Those not defined by the early planning documents should be established by negotiation with the contractor and the user; i.e., the operational command. All should then be regarded as minimum acceptable values to be achieved and demonstrated with the first articles to go into the operational inventory.

*Reliability of a given component or system is the probability that it will perform its required function under given conditions for a specified operating time.

If these numbers are to become firm contractual requirements, there must be agreement between the service and the contractor on at least four basic items:

a. Reliability level
b. Time or point in the program for achieving
c. Specific definitions of success or failure, and
d. Method for demonstrating compliance.

Developing satisfactory methods for demonstrating compliance is a difficult problem. Some of the reasons are the small number of flight articles, varying success criteria for different stages of a flight test program, design and model variations, and changing conditions of test.

It is not until late in the development cycle or perhaps as late as introduction of the system into the first operational units that all of these problems begin to resolve themselves. These considerations suggest that periodic review of progress throughout the growth cycle of systems, as proposed by the Ad Hoc Committee on Guided Missile Reliability,[2] is a necessary management tool. Also, that demonstration of the reliability of systems requires a carefully worked out plan to take advantage of all ground and flight tests. At some time in a program, however, it should be possible to demonstrate reliability with an adequate sample of the final articles under operational or essentially operational conditions. If this can be done, then agreement should be possible on the method of demonstrating contract compliance.

Since our ultimate objective is an optimum weapon system, this must be defined.[3] The requirements for a system, the design, and its effectiveness all flow directly from the mission of the system. We must know exactly what we want in order to get an optimum system. When a mission is well understood, an effectiveness model can be derived. The model would, in some way, give quantitative expression to the probability that a given design would successfully achieve the mission. The model would incorporate, directly or indirectly, all the performance parameters and design factors which determine the military worth of the system. Given such a model of effectiveness, it is then possible to determine tradeoffs among the variables that make up the model and define an optimum system.

A clear, explicit statement of the mission and a common measure of effectiveness will immeasurably simplify the problem of evaluating proposals for a specific system; i.e., it provides the necessary yardstick to select the best among competing designs. Further, its use puts a premium on the ability of contractors to discern the optimum system and will require contractors to make more realistic proposals both technically and costwise, leading to the balance of effort during a program necessary if we are to eliminate so-called problem areas. It goes without saying that design analysis must be a continuing effort throughout development to refine the system criteria so that we can realize our goal of an optimum system.

It is apparent then that the scope of analysis performed must be expanded. While we do not have all the methods or all the data we would like to have, the methods of systems analysis and operations research should be applied to provide the best possible basis for defining requirements which approach optimum values. While such analyses will obviously entail assumptions, it does identify assumptions as such. It will, so to speak, pull them out and lay them on the table for all to see. It should do much to reduce the danger inherent in management and design decisions in which the assumptions are well hidden and hence overlooked.

The approach, or perhaps I should say, the manner of thinking about requirements, which I have presented here is, I believe, reasonable. The stating of our design objective as an optimum weapon system and expanding the scope of systems analysis provides for work toward the proper ultimate goals. The requirements for minimum acceptable values for all success parameters should insure that first articles with operational configuration represent a usable system; i.e., available at the time specified, and capable of providing the required military capability on a continuing basis. The minimum requirements will be realistic if they can be achieved by the contractor in the time specified. Since contracts for systems to become a part of the inventory are awarded on the premise that the contractor can provide an operationally suitable article by that time, and that is precisely what is defined by the minimum requirements, they should be realistic.

Conclusion

This discussion has indicated the trends toward increased complexity, broader responsibilities in industry, higher-order systems, and increased costs. It has also noted the role of management and competitive buying in the reliability picture. All of these things have direct bearing on the need for establishing meaningful and realistic requirements for reliability. Increased emphasis on this area by both industry and the services is necessary, and will pay big dividends.

I have no illusions regarding the difficulty of defining good weapon system requirements and making them contractual requirements. I do feel, however, that we must work out many of the problems through experience. In the words of Task Group 1, AGREE,[4] the best way to arrive at *good* reliability requirements is to *begin the practice* of specifying reliability quantitatively—and this we are beginning to do.

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Statistical QUALITY CONTROL AND Reliability

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AMERICAN industry has been catapulted into vast projects for the manufacture of extremely complicated missile and nuclear equipment. The age of space exploration and the age of industrial automation, both of which are already upon us, as well as our national defense are completely dependent on intricate electronic systems. The job these systems must do puts unbelievable demands on precise performance and reliable operation.

Each of these systems is made up of hundreds or thousands of small components whose individual reliability determines the reliability of the overall system. The Nike Hercules System for example contains over 1½ million individual parts. The reliability of this system is dependent on the reliability of each individual resistor, capacitor, diode, transistor, relay, printed circuit, electron tube, transformer, soldered connection, valve, gear train, waveguide, oscillator, crystal, etc. *ad infinitum*. Using almost every type material and every fabricating operation, industry must build reliable performance into equipment of this magnitude.

The task is formidable. However, it must not only be done, it must be done economically.

It goes almost without saying that if these results are to be achieved many of the industrial practices of a vast number of contractors, sub-contractors, and suppliers must be very critically reviewed. Foremost among these practices is the use of engineering ability. The manufacture of material, components, and assemblies for equipment of the type we are discussing is from start to finish, an engineering job. It is engineering of the most demanding type. It requires that the full impact of engineering talent be brought to bear on every phase of operations with firm engineering control established over each step of every process. Additional engineering knowledge of process variables is essential. This necessitates process research and process engineering of a depth never before required.

This does not necessarily mean that more engineers are required. **It means only that engineering decisions based on anything other than research and experimentally verified conclusions are incompatible with reliability.** The engineering research required is the type we get when our engineers use Statistical Quality Control the way it was intended to be used.

Properly applied, Statistical Quality Control is the most scientific type of industrial research. It has as its goal the highest possible reliability at the lowest possible cost.

Unfortunately, much of industry has a rather long history of having viewed Statistical Quality Control from something other than a true perspective. For many years it has been all mixed up with inspection practices and inspection functions. It has been confused with acceptance and rejection concepts and with various plans for computing quality ratings of finished product. All of these are well and good but they are not Statistical Quality Control.

In order to take reliability seriously the first thing to do is clear away this confusion and arrive at an

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understanding of Statistical Quality Control that permits buckling down to the task of putting it to work. I would suggest that what is required is a return as it were to the well spring to refresh faith in basic concepts. The well spring is Shewhart.

It has now been almost 36 years since Shewhart first formulated the underlying theories of Statistical Quality Control. It has been 29 years since he published these theories in his book *Economic Control of Quality of Manufactured Product*. Among others, he made the following strong and positive statements[1]:

> The data of research are good or bad, depending upon whether or not assignable causes of variability have been eliminated.
> . . . it is practically impossible to sample for protective purposes unless the quality is controlled.

In all these years this science has not been advanced beyond Shewhart's original contributions. In addition much of industry has failed to bring its application even remotely near the level he so clearly visualized. This is a very important point to those responsible for the reliability of guided missiles or nuclear devices.

A State of Statistical Control Is Essential To Reliability

Shewhart's entire theory is based on the fact that the reliability of any manufacturing operation or of any engineering experiment is completely dependent upon the presence or absence of a "state of statistical control." If measurements representative of a given experiment or a given process reflect a state of statistical control then that experiment or that process is reliable. If not controlled the experiment or the process is not reliable. Shewhart's writings make crystal clear the need for every scientist and every engineer to keep foremost in mind one basic, inescapable truth: **If it's controlled we know. If it's not controlled we don't know.**

Let me cite an unmistakably clear statement from the editor's foreword to Shewhart's book *Statistical Method From The Viewpoint of Quality Control*[2]:

> . . . experiments that constitute the evidence for the inference must arise from a state of statistical control; until that state is reached . . . calculations by themselves are an illusion if not a delusion. The fact is that when distribution theory is not applicable for lack of control any inference, statistical or otherwise, is little better than conjecture. The state of statistical control is therefore the goal of all experimentation.

How does this tie in to reliability? Day in and day out industry on the one hand struggles with the difficulties of achieving reliability. On the other hand a multitude of hourly paid inspectors and testers is allowed to make important decisions regarding the acceptance or rejection of product. In making these decisions no one has any idea of whether or not the performance characteristics of the product result from a state of statistical control. In this connection Shewhart[1] speaks of:

> . . . the serious hopelessness of trying to predict the future in terms of the past when the chance cause system is not constant.

Said another way, as far as reliability is concerned the vast amounts of money spent on inspection and testing operations unaccompanied by Statistical Quality Control buy little better than conjecture—an illusion if not a delusion.

This does not mean inspection and testing operations can be eliminated. **It means only that if reliability is to be achieved these and all other operations must be engineered to the concepts of Statistical Quality Control** rather than to the concept of acceptance and rejection. The task of achieving this belongs to engineers—design engineers, product engineers, test planning engineers, quality control engineers and all others who in anyway influence the design or the production process. **A state of statistical control must be the goal of our entire effort—design, production and testing. This is the only known path to reliability. It is inescapable; it is incontrovertible.**

The Meaning of Statistical Quality Control

In order to see more clearly why such a positive statement is possible let us look more closely at the science of Statistical Quality Control. Perhaps the best place to begin is with the meaning of the term itself.

The word "statistical" means "having to do with numbers" or more particularly with "drawing conclusions from numbers." It is a very potent word because the conclusions are drawn from numbers through use of the powerful and reliable mathematics of distribution theory. In Statistical Quality Control the numbers are usually carefully taken measurements which contain information about what is happening in an industrial process.

The word "quality" may sound at first like an easier term than the word "statistical." Most of us think we know right away what it means. However, Shewhart devotes an entire chapter to its definition. He does this because the word "quality" is used in a special sense in the term "Statistical Quality Control" and we have to concentrate more on getting its true meaning. Quality is often associated in our minds with the goodness or badness of a product. Actually it means much more than that. Quality has the same meaning that it has when we use it in the plural and speak of qualities. The qualities of a process or a product are its characteristics — the things that make it such as it is.

The reliability of a guided missile is dependent on a host of characteristics or qualities in the missile. The missile itself is merely a container for the many qualities which make it a guided missile. The qualities may be good or they may be bad but in either case they are the characteristics that make it what it is. With Statistical Quality Control we can study the qualities or characteristics of any industrial process.

The complete meaning of the word "Control" is also rather difficult to grasp. Shewhart devotes many chapters to it. To control something is to keep it within boundaries or to make it behave the way we want it to behave. In Statistical Quality Control we control the characteristics of our production processes in order to make them behave the way we want them to behave. "Control" however, also has a more technical meaning in the phrase "Statistical Quality Control." It embodies the philosophy and the mathematics of distribution theory. It recognizes that everything is a variable and that individual variations are unpredictable. At the same time the central concept in this word is that groups of things form patterns with definite and permanent characteristics. Because of this the word "Control" defines predictability and reliability in that it describes the only constant we know of—the pattern of variation of a natural system of causes. In a profound breakthrough

in research techniques **Shewhart conceived the control chart as a major instrument of research and analysis. The control chart stands alone in its ability to discriminate between reliable and unreliable operations**—the presence or absence of a state of statistical control. Because of this its widespread use is indispensable to a realistic approach to reliability. As Shewhart wrote[3]:

> A state of statistical control can be approached only through the application of certain statistical techniques involving the use of the control chart.

By definition if a process is statistically controlled, its performance is predictable and therefore reliable. If it is not controlled, it is not predictable, and therefore it is not reliable.

With these meanings for each of the words in Statistical Quality Control let us put them together and see what the whole expression means.

STATISTICAL	With the help of numbers or data,
QUALITY	we can study the characteristics of
CONTROL	any process in order to make it behave the way we want it to behave

This, in simplest terms, is what we should have in mind when we speak of Statistical Quality Control. **It is the science of studying and engineering the behavior characteristics of production processes in order to achieve a state of statistical control.** The basic methods used are applicable to any process. They involve the refinement of processes through experimentation, the collection of objective data or facts regarding current process operations, the control chart analysis of these data, and the unyielding pursuit and control of the underlying causes affecting the process capability.

If our equipment is plagued with lack of reliability there is a reason for it. Behind each failure are causes which produced it. It is this system of causes which must be subjected to analysis and control. We want to find out what our process is now doing and why it is doing it. If we are not satisfied with what we find we want to change the cause system to secure the results we want. The Quality Control engineers' technical term for this type of applied research is "Process Capability Study." In it the three steps of hypothesis, experiment, and test of hypothesis are transferred from the laboratory to the shop floor and are used for the scientific analysis of complex cause and effect relationships. Through use of control charts the process capability study has enabled engineers to make process refinements which result in almost unbelievably small fractions defective. It has provided them with the key to research, analysis and control required for the solution of reliability problems because it provides the only known method for precise control of the causes which affect results. This is exactly what we are interested in when we are concerned with reliability.

It may be that as yet we have no satisfactory method for quantitative measurement of the reliability of a complex electronic system but it does not follow that reliability cannot be controlled.

The path for controlling reliability lies through control of the causes or variables which affect it. At every stage in the production process, from raw materials to finished product, the causes affecting important product characteristics must be persistently worked with until a state of statistical control is attained. Again, a state of statistical control must be the goal of our entire effort.

Small Quality Control Teams Afford the Best Means for Making Full Use of Statistical Quality Control

Achievement of this is a very specialized task. It is not likely that it will be accomplished by an independent group of engineers having the rather vague function of reliability engineering. Nor is it likely to be accomplished by a heterogeneous group of industrial engineers, inspectors, statisticians and mathematicians assigned the function of inspection engineering. It certainly cannot be accomplished by the screening effect of the inspection organizations now generally charged with protecting our reliability interests.

The best way yet found for effectively weaving the concepts of statistical control into the entire design and production process is through the joint effort of small quality control teams. Each team is made up of three members carefully selected from those who are closest to the production process. One member is the individual product engineer functionally responsible for providing the facilities and methods employed in the process. Another member is the first line supervisor functionally responsible for training, guiding and supervising the people who man the process. The third member is a quality control engineer capable of becoming thoroughly familiar with the production process and functionally responsible for providing a thorough knowledge of the concepts and application of statistical quality control.

Teams of this type are formed for each phase of every production process. The breadth of their assignment is generally defined by that portion of the process for which the supervisor and product engineer are otherwise responsible. It has been found that a qualified quality control engineer can serve simultaneously on a number of such teams.

The members of each team are, in addition to their other duties, assigned the task of making process capability studies of the characteristics of their process. As pointed out earlier this is a research program in which methods of scientific investigation are transferred from the laboratory to the shop floor for the purpose of analyzing and engineering the performance characteristics of the process. It has as its goal the elimination of all causes having an undesirable effect on the process operation and on the resulting product reliability.

This research and engineering is continued until the true process capability is reached. Reaching this point may require various revisions of the process, or even some product re-design. When this point is reached however, the process is operating in a predictable, reliable manner under a state of statistical control. Product reliability is at a maximum, rejects, junk and rework are at a minimum, yield is at a maximum, cost of operation is at a minimum. If any of these maximums or minimums are unacceptable **then and only then is a substantially different process or a substantially different product design required.** This is the economic control of quality of manufactured product which Shewart so clearly visualized.

Experience has shown that quality control teams, working to this objective, have been able to achieve surprising results with equally surprising rapidity.

Large savings in production costs have been documented. Total inspection effort has been substantially reduced and at the same time quality and reliability have been greatly improved. It has also been found that these teams are a particularly fruitful source of feed back information for the design engineer. The data they gather and their analyses of process variables provide invaluable information for setting tolerances. The teams very frequently discover characteristics in components received from a supplier that the supplier himself was completely unaware of. Many real improvements in suppliers' operations have been generated in this way. As these teams begin to gain proficiency the conditions surrounding the processes they work on undergo a noticeable change. Tensions ease and material and product flow more smoothly through the process. Operators acquire increased job interest and a new desire to improve their accuracy. There is a very noticeable reduction in the production and quality conferences that sometimes tie up rather large numbers of people. These and many others are the results of bringing the joint effort of the product engineer, first line supervisor, and quality control engineer to bear on their common job problems.

There is a reason for the success of these teams. It is best described in the editor's preface to Shewhart's book[2] *Statistical Method from the Viewpoint of Quality Control:*

> Most of us have thought of the statistician's work as that of measuring and predicting and planning, but few of us have thought it the statistician's duty to try to bring about changes in the things that he measures. It is evident, however, . . . that this viewpoint is absolutely essential if the statistician and the manufacturer or research worker are to make the most of each other's accomplishments. What they are capable of turning out jointly is the sum of their independent efforts augmented by a strong positive interaction term.

Working together in a closely knit team the product engineer, the first line supervisor and the quality control engineer are able to turn out the sum of their independent efforts plus a strong positive interaction term. Reflection shows why this is true; it has to do with the organizational level at which reliability problems are centered. The attitude of all levels of management toward reliability is extremely important. Full management support for the research and statistical control necessary to achieve reliability is essential. However, the reliability problems that concern industry have to do with the product design and the manufacturing process. Top management does not work intimately with either of these. Neither does middle management. We cannot therefore look to them to solve our reliability problems. Whether we realize it or not our products are designed and our production processes are run by engineers and first line supervisors. These two groups perform the lion's share of the very important management function of seeing that our products are reliably designed and reliably and economically produced We must therefore look to them for the solution to reliability problems. From the viewpoint of reliability the functions assigned them are so intricately related that they are indivisible. Thus their joint effort, augmented by the discriminating research of statistical quality control, is essential.

The Need for Especially Trained Quality Control Engineers

Perhaps at this point we should critically consider the need for having especially trained quality control engineers. In other words would it not be sufficient to teach quality control research methods to all engineers and not load our payroll with unnecessary specialists?

It is essential that all engineers have a sound appreciation and a good working knowledge of statistical quality control. However, the reasons for having specialists in this field lie in the depth to which the research must frequently extend. The structure of variables in manufacturing processes is extremely complex. Cause and effect relationships are sometimes obvious, sometimes subtle. Very often they are illusive in that they are particularly subject to change with time.

Let us examine this structure of variables more closely. Many of the variables which critically affect the reliability of our product are superficial. They can be found by almost anyone without benefit of scientific research. Examples of these are the untrained operator, the failure to follow directions, the unauthorized substitution of parts, careless handling, use of the wrong tool, omission of lubricant, improper baking temperature, wrong gauge, poor degreasing, etc. Finding and eliminating this portion of the cause system does not require the mathematical accuracy of statistical quality control. It primarily involves making people do the things they already know they should do. All such threats to reliability must be found and permanently eliminated. However, after they have been eliminated there still remains a deep structure of variables. Each mold, each oven, each tool, each machine, each test set, each material, each operator, etc. has its own individual characteristics capable of affecting reliability. Understanding this type of variable is often impossible without the accuracy of statistical analysis. Going even deeper we have various degrees of interaction between material and machine, machine and speed, material and temperature, material and time, method and material, method and speed, etc. Untangling these so they do not pile up large quantities of rejects or seriously impair reliability demands a high degree of analytical skill. Process capability studies in this area make long lasting improvements.

Going deeper yet we have such questions as why does processing Method 1 produce better results in some characteristics while Method 2 gives better results in others? Answers to questions such as this create new knowledge. To find such answers we need to discriminate between subtly balanced variables. **It takes an expert to handle the analysis of these types of problems and it takes time to train an expert.** By devoting full time to working with process variables, and becoming acquainted with the structure of variables through repetitive use of analytical methods the quality control engineer develops the required expertness. He comes to have a high respect for statistical accuracy. He gets to be an expert at reading the patterns on control charts. He knows the patterns are made by process variables and that process variables are the result of some cause. He acquires a facility for relating control chart patterns to the causes which affect the process and for relating causes to patterns. He learns to think in

terms of distributions — normal, skewed, unstable, mixed, stratified distributions, etc. As he works with the team to change or maneuver the cause system he carefully appraises the effect by translating it back to a distribution. He disciplines himself to doggedly pursue unsolved process problems. He develops an intuitive sense for dividing the process elements into rational sub-groups. He has unshakable confidence in the knowledge gained from control chart patterns. He also acquires a reverent respect for accuracy in data gathering. He knows how readily others overlook important aspects or conditions when identifying data. He knows that this one item alone frequently spells the difference between success or failure in important engineering investigations. He builds up a keen appreciation for the need of carefully and patiently instructing others in the method of selecting samples and taking measurements. He disciplines himself to follow up and make certain the methods are being correctly followed. Above all else he acquires a very profitable aversion to unfounded assumptions.

All this is expert knowledge. It does not come easily. Nor does it come to one not previously equipped with the inquisitive attributes of a good engineer or a good scientist. Quality control engineering is no place for those who have failed in other areas of science.

Much of the knowledge the quality control engineer acquires will transfer to the product engineer and the shop supervisor in the course of their normal team relationship. As a matter of fact another thing he soon learns is that the more of his special knowledge he can impart to others the more others can help him, thus increasing the productivity of both. This is the strong positive interaction.

There is however no limit to the special knowledge to be acquired in the science of analyzing the cause and effect relationships at work in industrial processes. Because of this, *real specialists in quality control engineering are both essential and extraordinarily productive employees.* Failure to recognize the difference between Statistical Quality Control and inspection has been a very costly mistake which is still being paid for in terms of missile failures and national prestige. Failure to recognize the need for thoroughly trained quality control engineers could well be another similarly costly error.

Before closing it should be emphatically pointed out that so far as is known there is no easy approach to finding answers for all reliability problems. Even with the most tireless efforts of quality control teams some reliability problems remain unsolved due to the present limit of knowledge. However, the use of quality control research leaves unsolved problems so defined and so separated that they can be made the focus of increased research unencumbered by the effect of other problems. Because of this it can be said that quality control teams diligently pursuing the state of statistical control which results in maximum yield, minimum costs and maximum reliability have unquestionably demonstrated that theirs is the path of the future.

References

(1) Shewhart, W. A., *Economic Control of Quality of Manufactured Product*, D. Van Nostrand Co., Inc.

(2) Shewhart, W. A., *Statistical Method from the Viewpoint of Quality Control*, Graduate School, Department of Agriculture, Washington, D.C.

Three Types of Quality

Quality of Type 1— That which characterizes the thing itself, independent of all other things.

Quality of Type 2— That which characterizes a thing A in relation to another thing B as a part of a whole.

Quality of Type 3— That which makes a thing wantable by some one or more persons.

Editorial Note—Shewhart defined three types of quality in his paper, "Some Aspects of Quality Control," *Mechanical Engineering*, Vol. 56, pp. 725-730, December 1934. M. J. Davis of the quality assurance department, Sandia Corp., has attempted to illustrate the three types in these cartoons.

A Reconsideration Of The

VARIABLES CONTROL CHART

With Special Reference to the Chemical Industries

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Abstract

QUALITY control problems in the chemical (and other) industries often require the use of techniques not commonly cited in the literature. One such technique that should be of particular value for the control of either batch-process or continuous-process operations is the Acceptance Control Chart. The Acceptance Control system is designed to provide action criteria that are based on consideration of the risks of accepting unsatisfactory processes as well as the risks of rejecting acceptable ones. Recognition is given the fact that a certain amount of variation in process level often can be tolerated in addition to the normal random variability, and that assignable causes producing level shifts within some acceptable range should not be flagged as "out of control." In essence, the process control operation is related to the quality requirements defined in the specifications.

A review of the fundamental assumptions of the Shewhart system is undertaken in order to contrast the purposes of the Shewhart Control Chart with those of the Acceptance Control Chart. This review is followed by a description of the Acceptance Control system and a specific detailed example of its application.

Introduction

The inauguration or revitalization of a statistical quality control program in the chemical (and almost all other) industries seems to evoke the same response: "In principle this looks fine, but it won't work here because our problems are different." There are two very good ways to be defeated by this statement. The first is to believe it and quit. The second is to ignore it and barge right ahead with the standard techniques.

The same fundamental principles do apply to almost all quality control problems regardless of industry or source, but the methods of application can and must vary according to the specific situation. The work of Shewhart,[1,2] who pioneered so ably in the development of the science of quality control, is often quoted and, unfortunately, often misapplied. This is not because Shewhart was unaware of the need to adapt the techniques to fit the particular case. Rather, it is because many of the writers who followed him have omitted, in the interest of expediency, readability, and salesmanship, many of the cautions and suggestions Shewhart offered. This is not to say that the applications discussed by these writers were incorrectly handled for the specific examples with which they dealt, or even that it might not have been more desirable to get an imperfect system under way than none at all. Instead, it is suggested that this may be a good time to review the fundamentals discussed by Shewhart.

But before we can apply principles of any sort, we must know just what it is we are trying to do. This is not always easy, for although life would be simple if we could content ourselves with doing only one thing at a time, we usually are far more ambitious. For instance, we often wish to evaluate product quality in three senses. We would like to compare the results of our efforts with the desires of the customer, with the quality of competitor's product, and with the previous performance of our manufacturing operation. And before the product has been completed, we want to be able to detect possible changes in the process, to diagnose existing or potential troubles, and to be in a position to recommend both long- and short-term corrective actions. The functions in which we are interested, either individually or in combination, are process control

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(the actual manufacturing operation), product acceptance (the disposition of the product), and product evaluation (the comparative rating).

With respect to the process control phase, Shewhart states that there are three steps in a quality control process. These involve the specification of what is wanted, the production of things to satisfy the specification, and the inspection of the things produced to see if they do satisfy the specification. He further states that statistical quality control may play an important role in obtaining the information necessary for establishing specifications that can be met, in serving as an operational technique for attaining uniform quality, and in providing a tool for judgment. In brief, it can be said that we generally are aiming for uniform quality at some desired level. In the final analysis, the choice of the degree of uniformity and the quality level must be a function of economic considerations. It was not accidental that the name of Shewhart's original work was *Economic Control of Manufactured Product*.

The Shewhart Control Chart

The best known statistical quality control tool used for process control is, of course, the control chart. The basic philosophy behind this technique is that knowledge about the previous performance of a process should be utilized to inform us about the uniformity of the current process and to indicate whether changes are occurring. Implicit in this approach is the recognition of two types of variation. The first is the inherent or random component associated with short-term variability in raw materials, handling, measurements, etc. This is essentially the noise level with which we have to live. The second is the variability associated with real changes in the process level and the assignable causes of these changes. This second category includes the signals that one wishes to detect over and above the noise level. The control limits delineate the region in which the noise level can be expected to fluctuate. Beyond these limits, it is assumed that the signal is real and that an assignable cause has resulted in a shift in process level.

We will see shortly that a new "Acceptance Control" concept may be more appropriate in many chemical industry applications, but nevertheless it is highly desirable to review some of the concepts involved in computing Shewhart control limits since a sizable part of this approach is carried over. To begin with, it is assumed in the Shewhart system that there is a stable process operating at some standard level. By a stable process is meant one that yields product that is essentially uniform. The random variability, or noise level, is the variation we would encounter about the standard level in such a stable process. It is measured by subdividing the data into "rational" subgroups. These rational subgroups usually represent a short period of time during which assignable causes are not likely to occur, but in which all of the sources of random error are free to have their effects. Time need not be the governing criterion. For example, a rational subgroup in a batch-processing operation might be associated with each batch prepared. In this case, the sources of inherent variability, or within-batch effects, could include minor local fluctuations in concentration due to imperfect mixing, the presence of small amounts of impurities, uneven removal of decomposition products, plus the various components of measurement error. The assignable causes should be associated with batch-to-batch (subgroup-to-subgroup) variations. Mixing errors, changes in raw materials, different operators, and varying starting conditions are some of the assignable causes that might produce shifts between batches.

The control chart approach is both logical and simple. The within-subgroup variability is used as a measure of the noise level. Ranges, or sample standard deviations, are computed to give an estimate of σ, the population standard deviation. Note that this measure of σ does not include group-to-group variations, but only the within-group components. Three sigma limits are usually* drawn about the established standard level, and if there is no shift in process level, 99.7 percent of the averages plotted should lie within the limits. Only 0.3 percent of the points plotted should exceed these limits as long as the process remains steady. But if the process level shifts, we would expect to find more points beyond the limits. When a point does plot outside the control limits, we must act on the basis that a signal has been received indicating that the process is "out of control", or, in other words, that there has been a shift in process level. Action is called for whenever a point exceeds the limits. The choice of the number of σ units (3σ, 2σ, etc.) that the control limits are located away from the standard line determines how often we will draw an erroneous conclusion that there has been a shift in process level even though the process is running at standard. For 3σ limits, the risk of this type of error is 0.3 percent. For 2σ, it is 5 percent. Rather than be tied down to any one level, let us talk about $t\sigma$ limits and call the risk of this type of error α. These probabilities must not be interpreted to mean that we can discount α percent of the "out of control" points. This interpretation might be fine for a historical review, but will not work in a control program. Failure to act on these points would in effect widen the zone associated with the noise level and make it far more difficult to recognize a legitimate signal. We can always avoid looking for non-existent trouble by never looking for anything at all. That is, we must balance the risks of calling wolf unnecessarily against the risks of not calling it until the sheep are being digested. If we have limits that are too loose we will not detect process shifts; and if we have limits that are too tight, we will be unable to run the process because of a continuous search for non-existing trouble. If we suspect that gross sampling or measurement errors are more likely to occur than assignable causes and we decide to resample every "out of control" point, we must then change our probability levels to satisfy this system.

Thus we want to determine the amount of noise we can tolerate for a given quality-cost picture. There are three direct ways to regulate the width of the noise belt. The first involves t, the number of sigma units that the limits are located away from the standard line and this has already been discussed. The second involves the selection of the sample size since the standard deviation of averages is the standard deviation of the original observations divided by $\sqrt{n}$ (where n is the sample size), and we are in effect reducing the size of σ by increasing the number of observations averaged.

*Two sigma limits are sometimes selected in preference to three sigma. The probability levels then become 95 percent and 5 percent instead of 99.7 percent and 0.3 percent.

The use of averages makes the control chart more powerful without increasing the α risk of unnecessary trouble hunting expeditions since t is unchanged. But the reduction in the width of the noise belt improves the chance of detecting real signals. Unfortunately, in many chemical industry problems, the cost of the improved filtering system achieved by increasing the sample size seems prohibitive, and hands are often thrown up at this point. One solution to the problem of getting some of the benefits of averages without an increase in cost will be discussed later; so for the moment let us assume that averages can be used. A major advantage of the use of averages is that averages of four or more observations will have a normal distribution in all cases usually encountered, regardless of the nature of the original population. Thus we can more readily make sound probability statements.

Finally, the size of σ is governed by the manner in which it is estimated. This is a point on which Shewhart spent quite some time, but which has been underemphasized in many of the case histories we are shown. By choosing a rational subgroup that is so homogeneous that only a relatively few of the sources of random error can come into play, σ will be small. By choosing a rational subgroup that is large and includes not only all sources of random error but also some assignable causes, σ will be relatively large. The first method leads to excessive control, the second to insensitive control. Many assignable causes produce effects that are real, but small and unimportant. In fact, it is often completely uneconomical to detect these effects, much less worry about how to correct them. For example, a shift in agitation rate may cause an increase in the photographic density of film being processed in a particular machine. Let us say that the increase is 0.01 density unit but that it would take a shift of 0.10 to be photographically important. The 0.01 density shift is real and the cause is assignable to the change in agitation rate. But it is certainly not worth having a point plot out of control to inform us of this situation. No one would want to shut down the machine for a few hours to correct something that does not materially affect the final product. Hence, it is often recommended that the standard deviation be inflated by selecting a subgroup that includes some assignable causes it would not pay to eliminate. Thus we see that the width of the control band may be regulated by the choice of the risk of looking for nonexistent trouble (the α risk, or producer's risk, which is a function of the selection of the number of σ units, t, that the control limit is located from the standard level), the sample size (the number of observations averaged in each plot), and the subgroups selected to furnish the estimate of σ.

If we are willing to assume that there exists only one standard level, and that we want to know whenever there is a sizable shift from that level, the Shewhart Control Chart is an excellent tool. There are many such situations and thus many applications call for the use of this control technique.

In the chemical industries, however, we encounter some problems for which the above assumptions are not the ones we wish to make. This means that we must then operate under a somewhat different system and spell out assumptions that are valid for the specific situations we wish to handle. Much of the Shewhart thinking will be included, and, in fact, it will be shown that the regular control chart turns out to be a special case (practically, although not philosophically) of this more general approach. The Acceptance Control System[3] which will now be discussed, is a blend of the Shewhart system and an acceptance sampling approach dealing with variables having a known standard deviation[4].

The Acceptance Control Chart

In the chemical industries we often are interested not merely in the problem of detecting a change in process level, but in deciding whether the change will result in the manufacture of "inferior" product. We usually expect to find shifts in the process level because of the complex nature of the manufacturing operations, and as long as these shifts remain small enough, it is rarely economical or even desirable from a quality viewpoint to try to eliminate them. The important qualification in the above sentence is "small enough." This means we must define acceptable and rejectable quality in terms of process levels, and we must recognize that these levels are the centers of distributions with variability equal to the random inherent variation.

The Acceptance Control system is designed to describe the protection against accepting processes that will result in an unsatisfactory quality level, in addition to the description of the protection against rejecting good processes that is included in the Shewhart system. Thus while the regular control charts concentrate on limiting the α risk associated with looking for nonexistent trouble, the Acceptance Control Chart simultaneously considers this α risk and the β risk associated with failing to detect trouble. In many chemical (and other) problems, this latter may be of even greater importance than the former and should be very seriously considered.

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Certainly, we cannot afford to ignore it. Also, under the Acceptance Control system, we no longer need a single standard line. We can have a zone about some nominal line and a process centered anywhere in this zone should be acceptable. That is, we can define how far the process can shift away from the nominal value and still produce material with an acceptable quality level.

It is at this point that the acceptance sampling origins of this system show up most clearly. As with any acceptance sampling system it is impossible to have a single dividing line to separate good from unsatisfactory quality without 100 percent inspection. This means we must locate the process level associated with a quality level we wish to accept almost all $(1 - \alpha)$ of the time it is being run. We call this the Acceptable Process Level (APL) and it marks the outer bound of the acceptable process zone located about the nominal value. Any process centered closer to the nominal value will have a risk of rejection even smaller than α, so that the closer the process is to target, the less likelihood there is that a satisfactory process will be rejected. We then must locate the process level we would want to reject* almost all of the time $(1 - \beta)$ it was run because it is associated with an undesirable quality level. This is labeled the Rejectable Process Level (RPL). The process levels lying between the APL and RPL would yield product of borderline quality (Fig. 1). That is, the quality there is not so good that it would be a waste of time if the process were adjusted, nor so bad that the product could not be used if no shift in level were made. This region is often called the "indifference zone." The width of this zone is a function of the particular process and the risks one is willing to take in connection with it. The narrower the zone, that is, the closer the APL and RPL are to each other, the larger the sample size will have to be. We will see that this approach will permit a very realistic appraisal of the effectiveness of any Acceptance Control system, and will provide a very descriptive method for showing just what any given control system is intended to do.

In the above discussion we have added something not considered in the usual Shewhart system. This is the relationship between the customer requirements and the process level. It is possible under this system to widen the limits and allow more freedom for some assignable causes to enter in those cases where tight control is not required. On the other hand, where customer requirements may be quite critical, this system will show how much sampling is required to provide the control necessary to do this more difficult job. These are the acceptance sampling characteristics.

The control characteristics will now be discussed. On the conventional control chart, it is not unusual to find that points tend to run about some line other than the standard level, but still remain within limits. And often, we find points plotting "out of control" although a look at many individual items taken at the same time does not show the expected number exceeding the natural tolerance limits. This is often due to the way σ was computed. The rational subgroups were either broadened to include some assignable causes, or σ was inflated directly to allow for

*The word reject is used throughout this paper in the sense of saying the process or product is unsatisfactory. No interpretation of whether the process should be stopped or adjusted, or whether product should be waived, scrapped or reworked is intended here. This is a function connected with the particular circumstances of a problem.

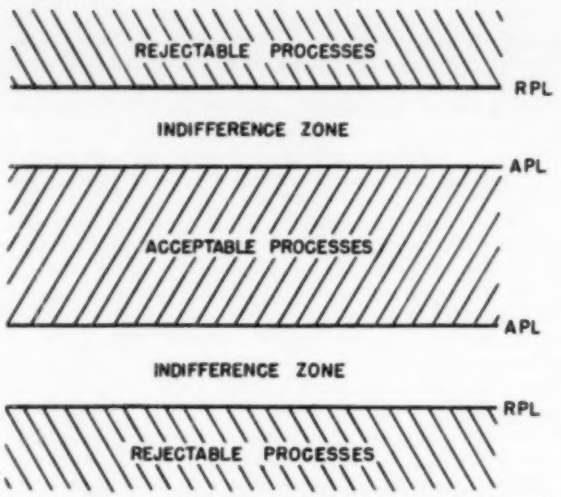

Figure 1—The APL and RPL Lines in Relation to Processes of Acceptable, Rejectable, and Indifferent (Borderline) Quality.

such uneconomical effects. What we are finding is that the process is in control with respect to random variability, not just at one level, but at whatever level these "unimportant" assignable causes may shift it. It boils down to this. The process is capable of running about a given level with small variability, until some minor assignable cause enters and shifts the level. Then it will run in control at that level, and so on. The trouble is that even though some of these assignable causes produce shifts in level that are acceptable, they enter the system at infrequent and irregular intervals. Sometimes they are random, sometimes they are not. By being lumped in with the random noise, they produce a somewhat confused system. This is not meant to imply that we can't get some real benefits from it even so. But we can obtain a much clearer picture of what is going on with the Acceptance Control system which tries to squarely face the problem of acceptable level shifts.

In the Acceptance Control system, the rational subgroup is chosen to contain only the random elements of variability, though every effort must be made not to exclude the effect of any random sources. An acceptance zone replaces the standard line. The width of this zone is determined by the amount of shift in process level that we wish to allow. In those cases where customer tolerances are wide, this can be a very wide zone since there often is no point in holding a process right on the line in this situation. In those cases where the tolerances are extremely tight, the zone may reduce to a single line (i.e., no assignable cause is considered too uneconomical to chase down) and we have the conventional control chart except that the sample size required to do the job we want done, will have been computed. When tight control is important, the more sensitive Cumulative Sum Chart described by Barnard in reference (5) should be considered.

A control chart for ranges or sample standard deviations should be run in this system just as in the Shewhart system. It is assumed above that the process will run in control for a period of time at some given level and then, when an assignable cause occurs, will shift to a new level but remain in control there. When σ is not known, it can be estimated by the usual $\bar{R}$ or $\bar{s}$ techniques, but a control chart should be run to keep a constant check on the basic

assumption that within-group variability has not changed. The relatively poor power of discrimination associated with measures of the standard deviation may call for the use of 2σ limits instead of the 3σ that are more customary for these charts.

It is now time to illustrate how these charts work in a specific example. Four terms have been mentioned above and we will see how any two of them will completely specify an Acceptance Control Chart for a given value of σ. These are the Acceptable Process Level (APL) with its associated α risk, the Rejectable Process Level (RPL) with its associated β risk, the Acceptance Control Limit (the action criterion), and the Sample Size (n).

Example

A film processing laboratory has several processing machines. While these are of essentially the same type, they have been installed over a period of years and minor improvements have been incorporated in the latest models. This has resulted in slightly different operating conditions for the various machines. These differences result in small, but real, photographic effects. However, owing to the replacement of parts and occasional machine overhaul, the photographic differences between the various machines are not constant over long periods of time. If the chemical levels, time of processing, bath temperatures, etc., are all held at their respective standards, the processes on the various machines will each be in control at a slightly different level. Over a long period of time, even more "in control" levels will be found because of the additional shifts due to adjustments.

Theoretically, all of these differences can be removed after each adjustment by "slaving" all the machines to a prescribed standard level*. But this would entail extremely difficult and costly procedures that would have to be repeated every time a part was replaced. The effectiveness of such a "slaving" program would have to be measured in terms of the improvement in quality gained for the price paid.

In this example, the quality requirements of the processing operation call for maintaining the density level of the film handled by the laboratory to within plus or minus 0.10 density units from a prescribed standard level. Changes smaller than this will not produce visual effects of importance to the viewer. The process variables that we want our operators to control are the time, temperature and chemical levels. The among-machine variations discussed previously can be held within $\pm$ 0.04 density units quite easily and within $\pm$ 0.03 units with a little more effort. If we wanted higher control than this, it would require the more difficult and costly "slaving" operation and we would like to avoid this, if possible. In addition, there are the normal random variations involved in sampling the control strips used for measuring densities, in exposing and reading these strips, and in the local within-process aberrations. A study of the random variability made by replicate within-subgroup measurements shows that $\sigma = 0.015$ and that the distribution of this random error is Normal.

Now a decision must be made concerning the operational definitions to be assigned to "acceptable" and "rejectable" processes. It is decided that if a process has as many as one percent of its strips with density readings beyond the specification limits of $\pm$ 0.10 units, we want to reject the process. Using a table of probability values for a Normal Distribution*, we would find that a process centered at 2.33σ, or 0.035 density units inside the $\pm$ 0.10 specification limits would be expected to have one percent of its density readings exceeding these limits (Fig. 2). Therefore, we say that $\pm$0.065 (*i.e.*, 0.100 — 0.035) are the Rejectable Process Levels† (RPL). That is, we want to be sure that a process centered as far out as $\pm$ 0.065 will be called unsatisfactory. Naturally, we will have to take a small risk, β, of failing to reject this from the first plot. (Note: It is not necessary to define the RPL in terms of the percent of individuals exceeding specification limits. Experience, competition, etc., may result in one selecting an arbitrary level such as $\pm$ 0.065 as being a process level we want to reject.)

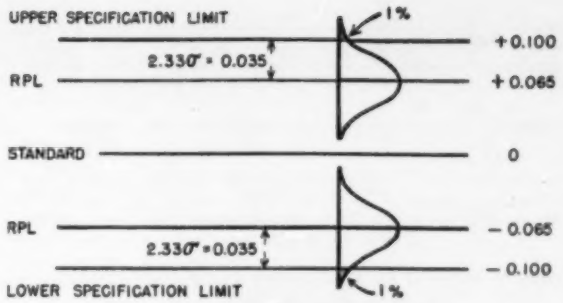

Figure 2—Method of Setting the RPL's

As was previously stated, we can easily keep the density shifts due to machine and adjustment differences to within $\pm$ 0.04 units. Since it is felt that processes centered at $\pm$ 0.04 will give very satisfactory quality, the Acceptable Process Levels (APL) can be established at these values. This means that we do not want to reject many processes (there will be an α risk of error) whose deviation from the standard level might be due to the type of machine variation with which it is uneconomical to bother. [Note that this has the interesting property that if the machine's adjustments are very well handled (kept near the nominal value), we are allowing more freedom for chemical, time, and temperature variations. But if we let the machines drift farther away from the standard, we require tighter control of these other factors.]

Let us assume that we choose to limit our α and β risks to five percent. Then we will find that our action criteria, the Acceptance Control Limits (ACL), will lie halfway* between the APL and RPL lines, or at $\pm$0.0525 [*i.e.*, ½ (0.065 + 0.040)]. (Figure 3) Our operating procedure will be that if an average (the sample size still must be determined) plots inside of $\pm$ 0.0525 we will accept the process, but if it plots outside we will reject it.

We need only draw the Acceptance Control Limits if simplicity is desired. The APL and RPL values need not be plotted, since they are used to inform the supervisor and engineer about the type of protection the system offers and are not action criteria.

*The term "slaving" is used to indicate a very strict program of making adjustments, taking measurements, and repetition of this cycle until the machine levels have been shifted to the standard level. Large samples are usually required if high precision is desired

*This procedure is valid for any distribution, Normal or not. If it is some other distribution, the probability values associated with that distribution should be used instead of the "Normal" tables.

†In this particular example, we are using limits on either side of the standard. In other cases, we may only be concerned with specifications in one direction.

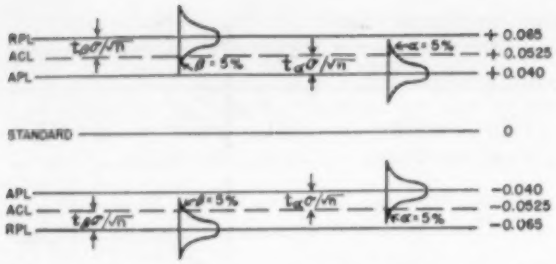

Figure 3—Method of Setting Acceptance Control Limits in Relation to RPL's and APL's

The sample size can be found by solving the equation*:

$$t_\alpha\sigma/\sqrt{n} + t_\beta\sigma/\sqrt{n} = \text{RPL} - \text{APL} \qquad (1)$$

$$n = \left[\frac{(t_\alpha + t_\beta)\,\sigma}{(\text{RPL} - \text{APL})}\right]^2$$

$$= \left[\frac{(1.645 + 1.645)(.015)}{(0.065 - 0.040)}\right]^2$$

$$= (1.97)^2 \approx 4$$

Thus four strips should be selected at random within a subgroup and their average plotted on the Acceptance Control Chart to be compared with the Acceptance Control Limits.

Should a sample size of four appear too large for practical purposes, it can be reduced by widening the indifference zone. That is, the APL might be shifted closer to the standard, requiring tighter control of the machine adjustments; the RPL might be shifted farther out, allowing the acceptance of a little poorer quality; or some combination of both may be chosen. For instance, let us say we wanted to limit the sample size to $n = 2$. Substituting in the left hand side of equation (1),

$$(1.645)\ (0.015)/\sqrt{2} + (1.645)\ (0.015)/\sqrt{2}$$
$$= \text{RPL} - \text{APL} = 0.035.$$

Thus, the indifference zone must be widened from 0.025 to 0.035. One way to widen the zone would be to shift the APL to $\pm$ 0.03. This might be a reasonable solution since in the introduction to the problem it was stated that with a little extra effort, the machine variations could be kept within this bound. As a consequence of the change in location of the APL, the Acceptance Control Limit would become 0.0475.

To carry this example to its extreme, let us say that a sample size of 1 (individual observations) is required by operational conditions.† Substituting in equation (1) as before, the indifference zone (RPL — APL) = 0.049. We could shift the APL from $\pm$ 0.040 to $\pm$ 0.016, but this would require too tight machine control. We could shift the RPL from $\pm$ 0.065 to $\pm$ 0.089, but this might permit acceptance of poorer quality processes. Or, as a compromise, we could move the APL to the $\pm$ 0.030 level discussed a moment ago, and also move the RPL out to $\pm$ 0.079 (keeping the β risk at five percent) and the ACL to $\pm$ 0.0545. The percent of density readings expected to exceed the specification limits at this new RPL will be eight percent instead of one percent. By using tables of the Normal Distribution, it can be shown that the β risk for the old RPL of $\pm$ 0.065 and its one percent "defective" level will have increased to almost 25 percent. That is, a process level that was originally defined as being quite poor would be accepted, when submitted, far more often if the sample size is reduced from four to one. By reducing the sample size, we are requiring tighter machine control and also relaxing our quality standards. This is one way in which the Acceptance Control system furnishes some additional information to be considered in selecting the sample sizes.

In many problems connected with the chemical industries we find strong pressures toward very small sample sizes, and especially for the use of individual observations. These pressures include such things as the length of time and costs involved in some chemical analyses, the difficulty in obtaining a sample, and the fact that very often repeated measurements do not represent all of the sources of random error, but are so restricted that they furnish little or no information beyond that furnished from a single observation. The disadvantages of using single observations are often quite strong also. In particular, we do not get the same power of discrimination that we would have if we could use averages. That is, the indifference zone must be larger. We must make more assumptions about the nature of the distribution, and if our assumptions are not good, our probability statements may be quite inaccurate.

One solution to this dilemma would be to consider two coincident types of control. The first uses a control system based on individual observations. Because of its poorer power of discrimination, the system will take larger risks of accepting poor quality. The second system involves grouping the results from several of the observations obtained for the first system. These could be averaged and plotted on what might be thought of as a longer range control chart. At these longer intervals, we would have a control system offering the tighter protection desired.

Let us consider this in the framework of the first example. Suppose we run one control strip every half hour. Then in half hour intervals we can check to make sure that gross shifts in process level have not occurred and we will have some check on smaller shifts, though with high β risks. At two hour intervals, we can average four such strips and by using a control system based on averages of four, we should have enough power to materially reduce our β risk. In effect, this double approach does the following. It says that we can risk a poor (but not grossly so) process level for a short interval of time, but that we will not accept it over a longer period.

In this particular illustration, we are considering anchoring at the same APL, with the RPL and ACL converging on this line with larger sample sizes.

*The actual computation of the ACL is the following: ACL = APL + $t_\alpha/(t_\alpha + t_\beta)$ (RPL-APL), where t_α and t_β represent the number of standard deviations away from zero that the α and β percents lie in a Normal distribution. In this case, $\alpha = \beta$ so that $t_\alpha/(t_\alpha + t_\beta) = 1/2$ and ACL = 0.0525. For most Acceptance Control Chart applications, "single tail" probability values are used for t_α and always for t_β. It is only when tight control is required that this does not hold. (Roughly ACL < 2.5 $\sigma/\sqrt{n}$ from standard for α = 5 percent. The σ here is often smaller than that for Shewhart limits were assignable causes may be included). A fuller discussion of this point plus tables that can be used to obtain the correct values in such "tight" situations is given in reference (3).

†In this problem, the random error has a Normal Distribution. In other problems, the distribution may not be Normal and the probabilities associated with averages of sample sizes smaller than four will be more difficult to obtain. Furthermore, if n = 1, occasional independent replications will be required to maintain a control chart for standard deviations.

Herein lies another advantage over the Shewhart chart. In the latter, as sample sizes increase, the control limits converge on the standard line. Thus, when a large number of points are averaged over an extensive period of time, long range control charts for each machine would indicate an out of control situation because of machine effects, even though short-term charts would show nothing wrong. In the Acceptance Control Chart, the convergence takes place out at the APL* so that the biases due to machines will not result in a long-term state of "lack of control."

General Comments

The first phase in the above example illustrates a situation in which the APL and RPL were the values used to establish the Acceptance Control system. In the second and third phases, it was the APL and sample size that were used. In certain other situations it is preferable to select the RPL and the sample size. For instance, if the specification limits are wide compared to the requirements for manufacturing control, a study of the economic and quality factors may suggest that a less rigid control system would be desirable. The wide specifications indicate that there is plenty of room in which the process can move around, but assurance is required that it will not shift "too much." The RPL is the definition of "too much" and the sample size is tied to the economic considerations. In some cases where a Shewhart control chart is currently being used, it may be of interest to determine the APL and RPL in order to evaluate the protection being offered. Here the control limit and the sample size are the values which specify the system.

In the example, we used equal α and β risks. This is not a requirement and different risk levels could be chosen if desired. It also was implied that losses in density were as important as increases since symmetrical limits were placed around the standard value. This also need not be the case since it is very easy to choose different APL and RPL values on the high and the low sides of the standard. Different levels of α and β also might be selected on the two sides if the consequences of an incorrect decision differ in importance.

There are other modifications that can be made to the system. For example, in some instances a restriction must be placed on the definition of acceptable process levels. Levels within the APL zone will all be acceptable on condition that no violent fluctuations occur within this region. That is, gradual drifts in process level may cause no difficulties in further operations, but a sudden shift from the lower APL to upper APL might be undesirable. Supplementing the Acceptance Control Chart with a control chart for differences between adjacent points should provide the necessary implementation of the added restriction.

The concept of a zone of acceptable process levels also ties in very well with the Evolutionary Operation procedures suggested by G. E. P. Box.[6] In Evolutionary Operation, the process may be shifted deliberately away from the standard level in accordance with some specified experimental design in order to gain information useful for product or process improvement. As long as the changes made in the various factor levels yield processes within the acceptable process zone, this valuable information about the process itself is collected without loss of quality and at little or no additional cost.

In conclusion, the Acceptance Control system draws heavily upon the Shewhart Control Chart and acceptance sampling techniques using variables. This blend seems to be especially appropriate for many of the problems found in the chemical industries. In particular, it has the advantage of relating the operation of process control to the need for this control by relating the acceptance control limits to specifications and by focusing attention on the protection against accepting poor quality processes as well as on the protection against rejecting good ones.

*It is very often more desirable to have the convergence take place at the ACL. The same control limit applies regardless of sample size, but the RPL and the APL change and converge on the ACL. Or, with larger samples we say we will want to be more strict about accepting "poor" quality and rejecting "good" quality processes and will work with smaller α and β risks.

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Management Looks At Quality Control

GEORGE A. PECK

Formerly with Stromberg Carlson, A Division of General Dynamics Corp., Rochester, N.Y.

I am vitally interested in quality. It is the basis for whatever success our company has achieved in the electronics field. It should not be necessary to dwell on the general importance of quality in a manufacturing enterprise, but you may be interested in the importance which management gives to the quality control function in Stromberg-Carlson. We think we are a versatile company, and the variety of items we deal with makes the quality problem a difficult one. We solve our problem by using the full gamut of quality control techniques. It is my purpose here to discuss the role of quality control as I see it from a management viewpoint.

Development of Quality Control

Although the history of quality control is generally well known, an assessment of the role of quality control today necessitates a look back for comparison purposes. Let me trace briefly the course that has been followed, so that we may ask where it leads.

Originally the task of inspection was not distinguished from the task of production. A craftsman inspected his own work. He did this to forestall complaints from his customers and to maintain his reputation. It was clearly the craftsman's reputation that was at stake.

ASQC LCS Code 300:10:400
George A. Peck, formerly vice president and general manager, electronics division, presented this address to the Binghamton section, ASQC, Dec. 16, 1958.

The Industrial Revolution must have changed this. The craftsman acquired a partner—a machine—and the machine was not capable of performing the task of inspecting its own output. How different the present might be, had the early inventors of machinery been imbued with the concept of automatic test equipment!

It is a long trail from the early craftsman to the quality control engineers of today. There has been much change, but this has occurred in an evolutionary fashion. We have not seen many abrupt changes in this development. The result is that the practices we follow today have been founded in experience, and tested in use. The danger, of course, is that one may tend to become skeptical about the need for further change.

Impact of Present Forces on Quality Control

Today there are many forces at work which will change the world of tomorrow. No one can continue his present way of life without considering what effect these forces may have upon him or his security.

Let us consider some of these forces and their possible effects. I would like to discuss such things as automation, military procurement, the emphasis on reliability and maintainability, the increased complexity of the things being manufactured, the need for increased precision, the need for lowered cost, the need for saving time, the need for new materials, new testing methods, new processes, new ideas. All these requirements or needs actually are demands which someone must satisfy. In our American system of enterprise there is an incentive to supply these needs. Competition is keen. The inspection function must offer new and better techniques to management to accommodate these needs as economically as possible.

Automation

We have become used to mechanization, for example, in the operation of a punch press, which performs a simple task and requires no directions, merely an off-on switch. We inspect the die and some of the parts the die produces, and there is little need to inspect all the parts so long as the die and press are properly used. Automation, however, presents new problems because of the added function of direction, or self-instruction, which the automatic machine performs. Perhaps it performs this by means of a punched tape. Holes in the tape instruct the machine to perform different operations.

Do we need to inspect the tape before and after each run, as we inspect the die in the punch press? Or do we allow it to wear out and cause the automated machine to turn out defective work? An answer may be that

we should sample the output and so maintain control of quality. But why do we not punch the kind of holes in the tape that will cause the machine to inspect its own work, and shut itself off when imperfect parts are about to be made? This is possible in some instances. I read some time ago of a machine which was designed to assemble transformer cores and which measured each piece of core material before assembly. When the addition of the best of the available pieces would result in assembly of a defective stack, the automated machine would not make the assembly—since this would be defective. Instead it shut off and signalled a shop supervisor to correct the trouble.

Automation offers quality control people an opportunity to extend their effort in the field of automated inspection, and automated control of quality. So far, most of the people designing automated processes have been production people. The result is a fast, automated process which has high volume output, and a bottlenecked inspection. Automation demands built-in assurance of quality. Should the quality control man leave this problem to be settled by management on a higher level? Or should the quality control people learn how to automate their own processes?

Complexity of Gadgets

There is a tendency to make everything much more complicated than used to be considered necessary. The hand choke on your automobile was long ago replaced by an automatic choke. This required more parts. It became more complex. Automatic can-openers are now being marketed. They run on electricity, and open cans for the housewife, who used to be content with a hand-operated device. The era of complex can-openers, of complex phonograph record changers, of four-speed, three-cycle washing machines, poses special problems for the quality control engineer. The problem of mating tolerances, variety of piece parts, versatility of inspection functions, all expand as complexity of manufactured product increases. The probability of error skyrockets.

What is the quality control engineer's answer to maintaining a good assurance of quality as complexity increases? Do we need more inspection operations? One answer to complexity is to break down the whole assembly into integral sub-units, which may be functionally tested before being put together as a whole.

Another answer to complexity is to tighten the tolerances on everything and hope that the product will go together more easily as a result. This is certainly an expensive way to solve the problem.

Is enough attention given to selection of those sub-assemblies which need a test prior to assembly as a whole? Is enough attention given to selecting those tolerances which need tightening, and opening those tolerances which can be loosened, so that what we spend on tightening tolerances can be saved through loosening of others? The important question is, "Are we getting the benefit of your specialized knowledge?"

Reliability of Gadgetry

As the complexity of the gadgets increases, our concern with their reliability or dependability must increase. It is a simple trick for the mathematician to show that as the number of parts increases, there is less probability that the device will work. Probability that the device will work when it is assembled is the *product* of the individual probabilities that the individual parts will work. It is not a sum. Much attention is being given to the reliability of things which are manufactured today, compared to the attention that was being given just a short time ago.

Reliability may be dismissed as a design matter, or as actually the customer's fault because he did not use the product right. What is the responsibility of the quality control man in each of these areas.

Reliability in the electronics business is occupying a great deal of the time of quality control people, and for two reasons: (1) quality control people appear to regard reliability as a characteristic *quality* of the product, and therefore their natural domain, and (2) the mathematics of reliability and the mathematics of quality control—i.e., probability—are the same, so that quality control people simply walked in on the ground floor and set up in business because they understood the language.

Is this enough? Have we fully faced up to other elements which determine reliability? For example, do we inject reliability considerations early enough? Should it not be a main concern of design engineering, or even of development engineering? Perhaps quality control should have a larger role in design committees and the feed-back from quality control experience given greater emphasis. Whatever the answers may be, main reliance must be on quality control people, for they are in the best position to measure and assure reliability.

Quality Personnel

The requirement of reliability of the final product results in a need for greatly increased reliability of the component parts. This is currently a problem in the electronics field, because it is only within the last few years that industry standards have been accepted in which the concept of the Acceptable Quality Level applies. Reliability requires that the parts continue to conform to all quality requirements, which in effect extends the concept of the AQL in time, as a life or longevity assurance.

This reliability concept has not yet been widely accepted. Its adoption places immediate burdens on quality control people to inspect for conformance—which involves us in extended life-testing, and therefore costs and time.

In the manufacturing of electron tubes, as well as in our own manufacture of telephone and electronic products, we have been aware of the importance of the long-term ability of products to meet the original performance requirements without degradation. The automobile and aircraft manufacturers have been confronted with this problem for many years. How reliable should parachutes be? How reliable should your tires be?

Quality control people, with their facility for dealing in statistical fields, have much to contribute to the definition, test methods of specification writing, communications, and finally assurances, in the field of reliability. Before long the concern for

dependability and for maintainability in the customer's hands will surely infiltrate into all industrial fields. Quality control people have already read the clear writing on the wall. But the basic problems of reliability are not yet solved. They present a challenge to all quality control people.

Environmental Requirements

Of course we did not need the urge of the reliability movement to acquaint us with the need to make a product that would stand up in severe environments. Many industries have long been involved in the design and testing of equipments or commodities which are used by the customer under especially severe conditions, For example, the shoes we wear were never meant to stay together after immersion in water; yet our children delight in wading through puddles. Do we find fault with the shoe manufacturer, or teach the children to stay out of puddles, or do we provide them with boots and rubbers to protect their shoes?

Translated into other terms, can we build equipment that will stand up under the rugged Alaskan winter while its companion equipments also perform in the Sahara desert? An aircraft creates terrific stresses in the equipment when the plane pulls out of a dive. We put a rubber boot on it in effect when we design resilient isolators into shockmounts for the equipment's protection against this abuse.

Many quality assurance problems are thus created. Some of these appear far afield from the usual routine of quality control. Because of this insistence on the customer's part in making use of our products in ways possibly not anticipated sufficiently, the effort of quality control is extended into new fields. Testing under conditions which simulate environmental extremes of temperature, humidity, shock, vibration, moisture resistance, altitude, certainly falls within the province of quality control and assurance. This leads to specialization, and new people with new skills enter the quality control area. This creates problems for both management and quality control, especially in the care we must take to indoctrinate these specialists in the policy and good practices we have taken so much care to work out.

Military Procurement

Our national economy today is so geared to our national defense effort that scarcely any industry can ignore the growing influence of military procurement in marketing its products. This is another force which is changing quality control practices, and its impact will eventually extend to products and businesses not now engaged in the manufacture of military material.

Some ten or eleven years ago the Air Force circulated for comment a proposed specification which would require manufacturers to establish a quality control organization. It was received with mixed feelings everywhere. Many were simply opposed to any attempt to dictate how we should conduct our inspection, or how we should organize for quality assurance. The Air Force indicated that it merely sought to standardize what was considered good practice, as a means of streamlining its own inspection and acceptance activities—with consequent savings to the taxpayer. Signal Corps offered a similar program. The Navy Bureau of Ordnance introduced its own quality control program. Today, after the hassle has subsided somewhat, it appears quite certain that all military procurement agencies will follow common quality control specifications now being adopted by the Department of Defense. There can be no doubt that this recognition of quality control as a necessary manufacturing function has helped the cause of quality control in non-military industries.

At the same time objections have been raised to other practices in military procurement, and legislation has been proposed in Congress to streamline the procedures. There has been much comment to the effect that a "pyramid of specification" creates a great burden on the manufacturer. Examples of the many pages of specifications required to list all the requirements for an ordinary can-opener and similar common articles have been read into the *Congressional Record*. Certainly the requirements for military equipment are numerous and detailed, and many consider this inevitable. However, this problem is one in which quality control people themselves have a large share of responsibility. Is there another, less cumbersome way of stating the quality requirements?

Weapons System Concept

A solution to the problem of the military procurement of complex equipments that has been gaining ground is the concept of the "Weapons System."

This simply means that the procuring agency instead of attempting to correlate the effort of several contractors and subcontractors through its own organization, lets the entire contract to a Weapons System Manager, who undertakes to supply whatever is needed, from the initial design through to the installation and servicing in the field.

The concept envisages that sub-contracting be done by the Weapons System Manager. In many ways this shortens the time required. It remains to be seen how far this procurement practice is to be extended. As with any other procurement or marketing practice which extends across a wide segment of our national economy, this concept will inevitably affect the way many of us conduct our business. It means, for example, that a quality control system would be set up by the System Manager, rather than by the procuring agency, and sub-contractors would undertake to comply with it.

This means that the burden of providing quality assurance would fall more and more on industrial quality control organizations, with a much broader scope of operations.

Training for Quality Control

The influx of more and more engineering personnel into the quality control field places a great responsibility on the profession for proper training in the basic subjects which are common to all quality control effort. Your National Society has organized for this effort, and today has within its framework various divisions such as the Textile Division, Chemical Division, Electronics Division, etc., devoted to the specialized work in these rather diverse fields.

We are constantly aware of the special courses organized for training in quality control. More and more engineering schools are adding quality control courses as elective subjects. An outstanding engineer and quality control man, Leslie E. Simon*, Maj. Gen., U. S. Army, Retired, once posed the question whether we should attempt to teach quality control people engineering, or teach quality control to engineers. It is now quite certain, as it no doubt was to General Simon then, that it is easier to teach quality control.

Scope and Depth of Quality Control Effort

We have discussed some of the forces which may cause changes in the role of quality control in industry.

If we look back at these practices in this country during World War II, we find that — with some exceptions — the effort was concentrated on intensive inspection. In one manufacturing department, for example, the inspectors lined up three deep: the Company Inspector, a prime contractor's inspector, and the Government Inspector. Each inspected the equipment in turn. Each had his own system of inspection, and a different color rejection tag. Each row of inspectors had to be serviced by a team of repairmen and a group of supervisors. Hannibal crossed the Alps with ease compared to the rigors of routing equipment through the Inspection Phalanx.

While this inspection was intensive, its scope was limited. Responsibility for quality at the point of production was considered a sufficient burden. At that time there was a movement to extend the application of quality control under the urgency of wartime requirements. It was applied on a basis of *no delay to production,* in too many instances.

Classes were held to acquaint inspection supervisors with the new concept of quality control. Frequently the sights were elevated to the limit because the target appeared so far away. Few of the rounds fired hit anything. The Inspection Supervisor, thus indoctrinated, undertook to "sell management." Frequently he failed to convince even the Chief Inspector. Too many production people were alienated by the jargon of *statistics.* At the end of the War there was something of a revulsion to the whole matter because of two factors:

1. The production department had had its fill of inspection in depth, and,
2. Retrenchment was widespread as industry tightened its belt for the plunge into the competitive struggle for existence.

The gains which quality control has made since that time have been fairly earned, sometimes in the face of a stiff and skeptical opposition. It learned to *pay* its way and *pave* its way for introducing change.

A well-known quality control authority, Joseph M. Juran, in a paper entitled "The Relationship between Staff and Line," now being distributed through the American Management Association, has some pertinent remarks to make on the subject of introducing changes. His advice may be paraphrased in this way: 1. Obtain the sanction of management so that your actions carry authority. 2. Enlist the support of the working man and his supervisor before you try to change their ways. 3. Show the production people that your innovation will help *them* do *their* jobs better.*

It is interesting to note that the quality control effort in many cases did begin by enlisting the support of the production workers and supervision on the operating level. It often even did not have the open support of management. Too often it sought to steal the limelight, taking too much credit for itself, instead of sharing the credit equally.

One of the early innovations was *sampling.* Although at first it met opposition because it permitted rejection of many parts after the inspection of only a few, sampling won acceptance because it was obviously more economical than sorting. Many production people have accepted sampling of their product without understanding the statistical basis. It is worth noting that many early quality control efforts failed because of undue emphasis on the technique rather than on the result.

Sampling methods still need to be extended to new applications. This is a fertile field for quality control, and will continue to be so for a long time. It needs to be extended in cooperation with other operations such as the manufacturing engineering or production engineering departments. Industrial engineers are becoming interested in sampling methods for work activity measurement. This is so much like acceptance sampling that it is surprising there is not more interest in this activity, compared to the interest, for example, in reliability.

May I point out that acceptance sampling was not an extension of quality control activity into a new area, but only a change in method of inspection. The application of sampling methods in work activity measurements, on the other hand, is an extension of the sampling technique into a new area, replacing or supplementing time study methods, which is not a normal quality control function.

Should Quality Control participate in work activity measurement? Let me ask what we know about the work activity of inspection workers? Quality Control might make a beginning in its own backyard, and if the effort appears profitable, help extend the application to the production area. At least this would be preferable to attempting to apply sampling of work activity first to the production area, and later to inspection.

One might also inquire what is known about inspection effectiveness. How many of the defects that exist are found by inspection? How many are left for the customer to find? Much has been written about the calculation of process averages for measuring the effectiveness of production processes. Not enough has been done about measuring the process average of inspection operations. Again, Quality Control might do well to make a beginning in its own backyard before extending its activities.

There probably are other areas of inspection and testing in which the application of quality control techniques could result

*Now director of research and development, The Carborundum Co., Niagara Falls, N. Y.

Editorial Note: Dr. Juran's paper "Cultural Patterns and Quality Control," October 1957, IQC, and the Vol. XIV Brumbaugh Award winner develops and presents this same theme.

in improvement, which are best known to quality control people, like the familiar skeleton in the closet.

Management support for the improvement of inspection and testing processes ought not be difficult to obtain. Thus earned, management support would be more easily obtained for other activities.

The Place of Quality Control in the Organization

It is interesting to observe that there is a remarkably persistent effort to extend quality control activities into other areas. Quality control people seem to be imbued with the missionary spirit.

Opposed to this, there is a die-hard opinion that quality control is simply a new name for inspection of the product—when absolutely necessary — at the point of manufacture. These views are in direct opposition. Management is sometimes acutely aware of the problem of the proper place for quality control in the organization.

Those who champion the extension of quality control activity are not attacking a limited objective. The concept of Total Quality Control extends the responsibility from the product cradle to the grave, from engineering design to the customer, and through the customer's experience to engineering redesign in endless cycles. Quality control's backfield, the mathematician, has long advocated the application of statistical methods to the design of experiments which result in product development as well as to the evaluation of customers' complaints, ending in design re-evaluation.

What is to be the attitude of management toward this infiltration and penetration? There is an increasing tendency to allow this extension of quality control to proceed as far as the applications prove worthwhile. This amounts to a paternal acquiescence in permitting quality control to find its own place in the organization, like an unruly boy who is too hard to handle. I am sure, however, that this experiment, like the others, can be designed, blueprinted, and tested, and need not occur at some random time, like a chance event.

In our own organization quality control performs the customary functions, and reports to the Vice President and General Manager on a level with the Engineering, Manufacturing, and Marketing activities. It works closely with these departments, and there is no particular problem of its proper scope, or place in the organization.

Operations Research

There is today a movement, sometimes difficult to define, which in its scope and in the zeal of its advocates bears a remarkable resemblance to quality control. It is called *Operations Research*. The story of its wartime activities has not been fully disclosed, but certain of its reported accomplishments appear quite remarkable. One of its stated objectives is the formulation of decision-making rules for management. It differs from quality control in that its effort is directed initially at management acceptance rather than at acceptance on the working supervisory level.

Decision-making rules formulated by operations research are not limited to management activity on a corporate level, but extend to manufacturing areas as well. Problems in machine loading, scheduling, inventory control, allocation, transportation, warehousing, and marketing, are attacked, and methods evolved for their optimum solution. Some of the methods are simple applications of mathematics to everyday problems, and some are complex enough to warrent use of computers for their solution.

While quality control people in general have not wholeheartedly joined with the advocates of operations research, there is evidence of collaboration. However, production control people and industrial engineering people share the interest in this new approach to problem solving. Operations research is one of the forces at work which may be capable of causing changes in the quality control area.

Queuing Theory

A topic of interest in the purview of operations research which may well arouse interest among more quality control people is the matter of the waiting line, or Queuing Theory.

This deals with the probable length of a line of people, or of materials in the "pipe line" if you prefer, which forms ahead of some following process such as the next manufacturing operation, or inspection. The problems solved by this application of mathematics include the number of maintenance men required to service a battery of machines, so as to minimize "down time" and yet hold the number of maintenance workers to a minimum. Translated into quality control language this would include problems of the number of inspectors required to keep in-process inventory to a minimum, or the number of units likely to be found ahead of inspection to minimize the number of idle inspectors. It would appear to be a matter worthy of investigation to determine its value.

The tool of mathematics in operations research is the same tool used in quality control. Quality control is espoused as a tool of management. Therefore a larger scope appears to be formulating for quality control personnel in the management complex via the decision-making process, or if you will, the quality of management decisions. Isn't this role a challenge worthy of consideration?

Management Attitude in Quality Control

Previously mentioned were two matters — training in quality control, and the place of quality control in the organization. Taken together these matters call attention to the training of individuals for places in the organization. What is the attitude of quality control people in general toward their place in the management organization? Are they primarily quality control minded, or management minded?

Considerable orientation is required to make a production man or an engineer into a quality control man. How much orientation is needed to make a quality control man into a member of management?

In our organization we have introduced a rotational training program in which people from various departments are given an opportunity to spend sched-

uled periods in each of many departments. These departments include Engineering, Marketing, Production Engineering, Manufacturing, Production Control, Purchasing, Plant Engineering, and Quality Control. Some trainees also are entered in the program directly from engineering schools. On completion of the program, the trainees are returned to their original departments with a new concept of the organization's varied functions, or are transferred to other departments when the change is a matter of mutual desire. This program contains the elements of a broader concept of management training, and possibly promotes the closer integration of the departments concerned. The reactions to this program are stimulating and encouraging. It tends to overcome some of the limitations in point of view which characterize people in specialized jobs, and broadens the perspective. Whether we participate in such a management training program or not, all of us are constantly training and being trained by those we come in contact with in the industrial organization.

Conclusion

In summary, the role of Quality Control, from our cursory review, appears to be quite an expanded one, and will probably continue to increase.

We have seen how, with compressed time cycles in development, quality control personnel must get into early engineering development phases to monitor verification of design by intensive tests. The task continues through the production cycle to give the customer reasonable assurance of an acceptable product. The role continues in order to assure customer satisfaction in actual field operations. The scope is now practically from inception to field use.

The depth of the role of quality control has similarly increased from the floor inspector to a position in the upper levels of management. The role thus has expanded horizontally and vertically. A professional status has been achieved and the quality control function has become an integral part of management. Management should see that it uses this tool properly.

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Critical Sigma d^2 Values

For Rank Order Correlations

KLARE L. TEEGARDEN

Bristol Laboratories, Syracuse, N. Y.

IN preliminary analysis it is often necessary to run a fairly large number of correlations. In this case, the rank order correlation coefficient may be used to save time, since we are "searching" rather than seeking the accuracy that would be obtained by Pearsonian correlation coefficients.

Let's say we have the situation where we want to determine if any one of nine independent variables is related to any one of four dependent variables. This requires the calculation of 36 rank correlation coefficients. In this problem we are interested in two things: (1) are the relationships positive or negative, and (2) are the relationships significant?

A series of multiple correlations is applicable here; however, since this is a preliminary analysis, the quality and quantity of the data may not warrant this advanced technique; also it may be deemed too time consuming and/or expensive at this stage of the process development.

By setting up a table for the critical values of Σd^2, the above mentioned decisions can be made as soon as the value of Σd^2 is known.[1] This eliminates three operations, namely: the multiplication of Σd^2 by 6; the division of this product $6(\Sigma d^2)$ by $(n^3 - n)$; and the subtraction of this value $6(\Sigma d^2)/n^3 - n$ from 1. On the 36 calculations of ρ (the rank correlation statistic) that are being considered, this will save 108 distinct operations.

The critical Σd^2 values in Table I are based on critical ρ values from a one-tailed, rank correlation coefficient table.[2]

The standard formula for the rank correlation coefficient is:

$$\rho = 1 - \frac{6(\Sigma d^2)}{n^3 - n}$$

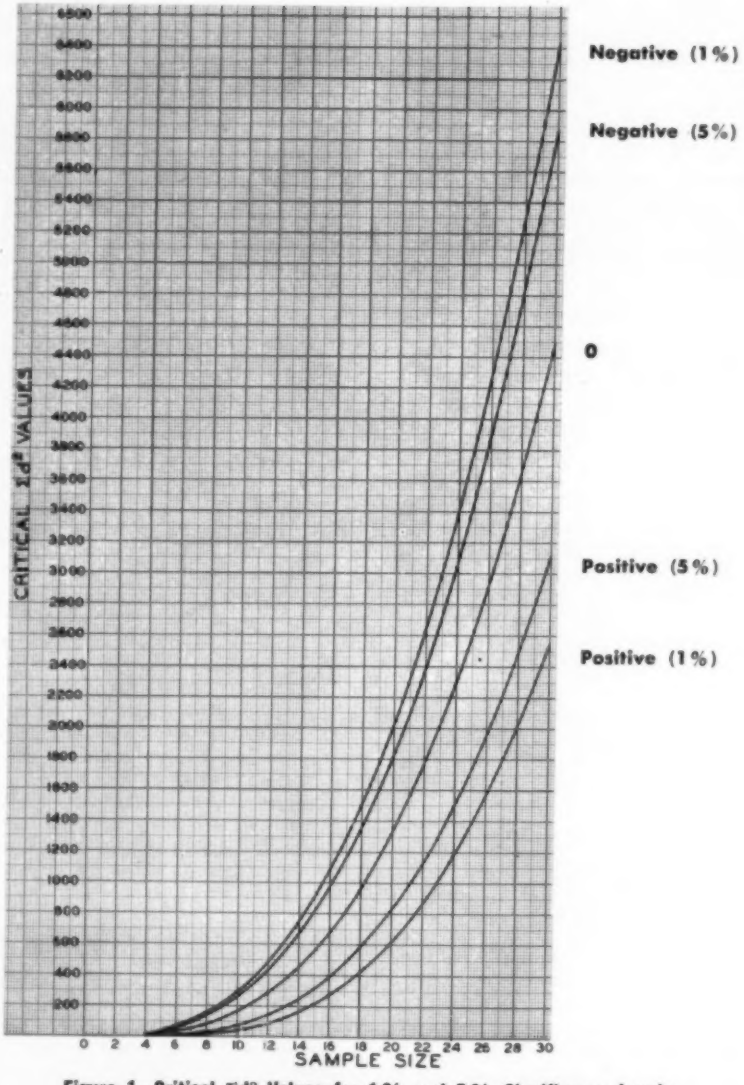

Figure 1—Critical Σd^2 Values for 1% and 5% Significance Levels

ASQC LCS Codes 553:60;70:400

By solving for Σd^2 as below:

Positive (+)

$$1 - \rho = \frac{6(\Sigma d^2)}{n^3 - n}$$

$$(1 - \rho)(n^3 - n) = 6\ \Sigma d^2$$

$$\frac{(1 - \rho)(n^3 - n)}{6} = \Sigma d^2$$

Negative (−)

$$1 - (-\rho) = \frac{6(\Sigma d^2)}{n^3 - n}$$

$$(1 + \rho)(n^3 - n) = 6\ \Sigma d^2$$

$$\frac{(1 + \rho)(n^3 - n)}{6} = \Sigma d^2$$

and then substituting various values of n and the critical values of ρ (for the corresponding values of n), the critical Σd^2 values, for both positive and negative significant rank correlations, can be calculated.

The Σd^2 giving a rank correlation coefficient of 0 (zero) is equal to $(n^3 - n)/6$. When the correlation is not significant, this value of Σd^2 facilitates the decision of whether the relation tends to be positive or negative.

Consider as an example the data for two variables X and Y as given in Table II. From the 5% significance level in Table I we find that the Σd^2 value at $n = 8$ is 138.0. Since in the example Σd^2 is 152.5, the correlation is significant and indicates an inverse relationship.

The Figure 1 curves may be used instead of the table; this eliminates the need for interpolation for values of n not shown in the table. If the Σd^2 value is equal to or greater than the upper (negative) curve, then the relationship is significant and inverse. If the Σd^2 value is equal to or less than the lower (positive) curve. then the relationship is significant and direct. If the Σd^2 value lies between the upper and lower curves, then relationship is not significant but whether it tends to be inverse or direct can be determined by which side of the center (0) curve it falls.

In summation: if the Σd^2 is $\leq$ the critical value in the plus (+) column of the table, the correlation is significant and direct; conversely if the Σd^2 is $\geq$ the critical value in the minus (−) column of the table, the correlation is significant and inverse. If there is no relationship between the variables, then the Σd^2 should equal the value in the center (0) column of the table.

References

(1) Bennett, C. A. and Franklin, N. L., *Statistical Analysis in Chemistry and the Chemical Industry*, pp. 283-286; Wiley and Sons 1954

(2) Dixon, W. J. and Massey, F. J., Jr., *Introduction to Statistical Analysis*, p. 468, McGraw-Hill Inc. 1957

TABLE I—Critical Values for Σd^2 of Rank Order Correlation

	5% level			1% level		
n	+	0	−	+	0	−
4	0	10	20.0			
5	2.0	20	38.0	0	20	40.0
6	6.0	35	64.0	2.0	35	68.0
7	16.0	56	96.0	6.0	56	106.0
8	30.0	84	138.0	14.0	84	154.0
9	48.0	120	192.0	26.0	120	214.0
10	72.0	165	258.1	41.9	165	288.1
12	141.3	286	430.7	82.4	286	489.6
14	247.5	455	662.5	161.5	455	748.5
16	391.0	680	969.0	271.3	680	1088.7
18	582.4	969	1355.6	422.5	969	1515.5
20	828.6	1330	1831.4	619.8	1330	2040.2
22	1135.2	1771	2406.8	871.3	1771	2670.7
24	1511.1	2300	3088.9	1184.5	2300	3415.5
26	1962.7	2925	3887.3	1564.9	2925	4285.1
28	2495.7	3654	4812.3	2017.0	3654	5291.0
30	3119.5	4495	5870.5	2553.2	4495	6436.8

TABLE II—Sample Data

Variable X	Rank of Variable X	Variable Y	Rank of Variable Y	d	d^2
374	4.5	15.6	5	0.5	0.25
374	4.5	16.5	4	0.5	0.25
372	6	17.3	1	5	25
368	7	16.9	3	4	16
366	8	17.0	2	6	36
379	1	14.1	6	5	25
376	3	8.6	8	5	25
377	2	13.4	7	5	25
					152.50 = Σd^2

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Quality Control – The Golden Gate to Higher Profits

14th Annual Convention and Exhibition

MONDAY, MAY 23, 1960

6:00- 9:00 pm Pre-Convention Wine Tasting Party — **Gold Ballroom**

TUESDAY, MAY 24, 1960

8:00- 9:30 am **Registration**

9:00 **Exhibits Open** — **Rose**

9:30-10:30 — **Gold Ballroom**

Welcome to the Convention
Harter G. Hudson, general chairman, 14th Annual Convention Committee
C. E. Fisher, president, ASQC
Keynote Address:
Rudolph F. Bannow, president, National Association of Manufacturers

VISIT EXHIBITS — **Rose**

11:00-12:00

Insp. Wksp "Setting the Theme" — **Concert**
Ray E. Primmer, president QRA, Van Nuys, California
Moderator: R. Calvert Haws, president, Quality Control Engineers, Inc., Los Angeles, California

2A Panel Discussion: "ASQC Education & Training" — **Comstock**
Moderator: A. W. Wortham, manager, Planning and Management Systems, Texas Instruments, Inc., Dallas, Texas
Ellis R. Ott, director, the Statistics Center, Rutgers - the State University, New Brunswick, N. J.
David S. Chambers, associate professor of statistics, University of Tennessee, Knoxville, Tenn.

2B "A Short Survey of Management's Use of Operations Research" — **California**
T. E. Caywood, partner, Caywood-Schiller Associates, Chicago, Ill.
Moderator: Dale L. Lobsinger, quality control superintendent, United Air Lines, Denver, Colo.

11:30-12:30

2C "Response Surface Techniques" — **French**
Donald A. Gardiner, Statistics Section, Oak Ridge National Laboratory, Oak Ridge, Tenn.
Moderator: Horace Andrews, statistician, Research Laboratory, Swift and Company, Chicago, Ill.

2D "Quality Control and Reliability" — **285**
Frank H. Squires, management consultant, Los Angeles, Calif.
Moderator: Leon Bass, manager of quality control, Jet Engine Dept., General Electric Company, Cincinnati, Ohio

2E "Use of SQC in the Container Manufacturing Industry" — **Parlor A**
Robert B. Fry, eastern division manager, Quality Control, Continental Can Company, New York, N. Y.
Moderator: Howard L. Stier, director of statistics, National Canners' Association, Washington, D. C.

1:30- 5:30 pm Plant Tours:
Owens-Illinois Glass Company, Oakland
Eitel McCullough, San Bruno
Hexcell Products, Oakland

1:30- 2:30

Insp. Wksp "How Accurate Are Your Measurements?" — **Concert**
Roy A. Wylie, quality control manager, AMPEX Corporation, Redwood City, Calif.
Moderator: R. Calvert Haws

3A "The Quality Assurance Management Approach to Supplier-Consumer Problems" — **Comstock**
Harvey Christen, director of quality control, California Division, Lockheed Aircraft Corporation, Burbank, California
Moderator: Paul E. Allen, manager quality control and customers service, Beech Aircraft Corporation, Wichita, Kans.

3B "The Measurement and Specification of Product 'Abilities'" — **California**
H. Dean Voegtlen, manager reliability research projects, RCA Service Company, Rome, N. Y.
Moderator: John H. Yueh, research engineer, Missile Systems Division, Lockheed Aircraft Corporation, Sunnyvale, Calif.

VISIT EXHIBITS — **Rose**

2:00- 3:00

3C "Application of OR at Shell" — **French**
Paul Stillson, Shell Development Company, Emeryville, Calif.

3D "Theory of Experimental Designs" — **Parlor A**
Carl A. Bennett, manager operations research, Hanford Works, General Electric Company, Richland, Wash.
Moderator: Enoch B. Ferrell, switching research engineer, Bell Telephone Laboratories, Murray Hill, N. J.

VISIT EXHIBITS — **Rose**

3:00- 4:00

Insp. Wksp "The Inspector's Place in Quality Control" — **Concert**
Frank H. Squires
Moderator: R. Calvert Haws

4A Panel Discussion: "Management's Concepts of QC Responsibilities" — **Gold Ballroom**
Moderator: E.G.D. Paterson, director of quality assurance, Bell Telephone Laboratories, New York, N. Y.
William J. Masser, manager quality control, General Electric Company, New York, N. Y.
Paul C. Clifford, professor of mathematics, Montclair Teachers College, Montclair, N. J.

4B "Weapon System Management For Quality" — **Comstock**
John W. Young, corporate director, quality and logistics, North American Aviation, Inc., Los Angeles, Calif.
Moderator: E. J. Lancaster, chief quality control, Ballistic Missile Center, Inglewood, Calif.

4C "Statistical Quality Control Applications in the Food Industry" — **California**
Charles B. Way, quality control manager, Green Giant Company, Le Sueur, Minn.
Moderator: Gordon A. Rowe, University of California, Berkeley, Calif.

3:30- 4:30

4D "When Is a Small Sample Large Enough?" — **French**
Edward P. Coleman, professor of engineering, University of California, Los Angeles, Calif.
Moderator: Leo Aroian, Systems Development Laboratories, Hughes Aircraft Company, Culver City, Calif.

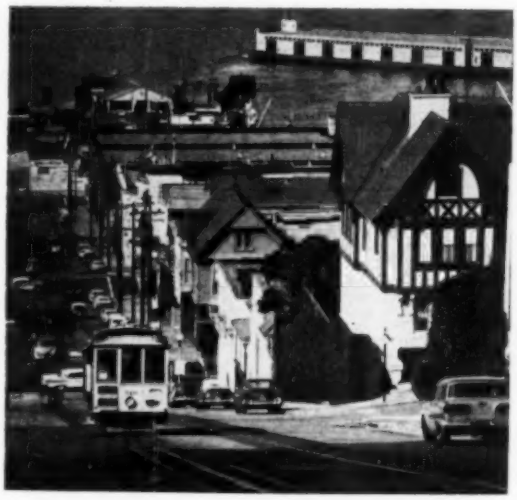
4E "How To Plan and Implement an Incoming Material Control Program" — **285**
Chester Gadzinski, consultant manufacturing services, Raytheon Manufacturing Company, Waltham, Mass.
Moderator: Henry I. Matosoff, chief quality engineer, Cannon Electric Company, Los Angeles, Calif.

4F "Raising Production in Indian Industry Through Quality Control" — **Parlor A**
William R. Pabst, Jr., chief statistician, Bureau of Naval Weapons, Department of Defense, Washington, D. C.
Moderator: H. Mack Truax, Atlas Powder Company, Wilmington, Dela.

4:45 Annual Meeting of ASQC — **Gold Ballroom**

6:00 Exhibits Close

9:00 pm Social Evening — **Gold Ballroom**



WEDNESDAY, MAY 25, 1960

8:00- 9:00 am Registration — **Rose**

9:00 Exhibits Open — **Gold Ballroom**

9:00-10:00

Opening Remarks
Stanley J. Hotchner, chairman, San Francisco Bay Area Section
J. Y. McClure, vice president, ASQC
Special Address: "Reliability of Guided Missiles"
Rear Admiral Paul D. Stroop, chief, Bureau of Naval Weapons

VISIT EXHIBITS — **Rose**

10:15-11:15

Insp. Wksp "Training Inspectors and Apprentices" — **Concert**
Frank W. Mitchell, quality control manager, Ensign Carburetor, Fullertown, Calif.
Moderator: Ray E. Primmer

5A Panel Discussion: "Progress in Quality Control for 1959" — **Gold Ballroom**
Moderator: John J. Riordan, staff director for inspection and quality control, Office of Secretary of Defense, Washington, D. C.
Colonel J. G. Schneider, chief quality control, Headquarters, Air Material Command, Wright-Patterson AFB, Ohio
Colonel Eldon A. Koerner, chief standards branch, Deputy Chief of Staff for Logistics, Department of the Army, Washington, D. C.
Captain G. L. Heap, director, field services division, Office of Naval Material, Department of the Navy, Washington, D. C.

5B "Video-Sonic Instructions Raise Quality Standards" — **Comstock**
David A. Hill, manager, Semiconductor Division, Hughes Aircraft Company, Newport Beach, Calif.
Moderator: Frank E. Grubbs, Ballistic Research Laboratories, Aberdeen Proving Grounds, Aberdeen, Md.

5C "Calibration Requirements for Government Contractors" — **California**
William B. Rice, head, Measurement Standards Department, Aerojet-General Corporation, Azusa, Calif.
Moderator: S. J. Skolnik, inspection specialist, Quartermaster General, Department of the Army, Washington, D. C.

VISIT EXHIBITS — **Rose**

10:45-11:45

5D "Audit Testing" — **French**
C. W. Carter, Industrial Management Consultant, Longmeadow, Mass.
Moderator: W. James Penrose, project manager, Federal Systems Division, IBM Corporation, Kingston, N. Y.

5E "Variations of Mechanical Properties in Aluminum Products" — **285**
William P. Goepfert, head, Statistical Analysis Department, Aluminum Company of America, Pittsburgh, Pa.
Moderator: George F. White, Jr., quality control engineer, Reynolds Metal Company, Richmond, Va.

5F "Integrated SQC in Food Processing" — **Parlor A**
Charles R. Shaeffer, manager quality control, Frozen Foods Division, Stokley-Van Camp, Inc., Oakland, Calif.
Moderator: Amihud Kramer, food processing specialist, University of Maryland, College Park, Md.

VISIT EXHIBITS — **Rose**

11:45-12:45

Insp. Wksp "Incoming vs Vendor Source Inspection" — **Concert**
Charles H. Hutcherson, general foreman, Procurement and Inspection, North American Aviation Co., Los Angeles, Calif.
Moderator: Ray E. Primmer

6A "Variables Sampling" — **California**
Gerald J. Lieberman, assistant professor of statistics and industrial engineering, Department of Statistics, Stanford University, Stanford, Calif.
Moderator: Carl E. Noble, manager customer acceptance, Kimberly Clark Corporation, Neenah, Wis.

6B "Some Statistical Concepts Applied to the Navy Calibration Program" — **French**
Stanley Crandon, head, Field Operations Division, Metrology Department, Bureau of Naval Weapons Representative, Pomona, Calif.
Moderator: Max Astrachan, professor of statistics, USAF Institute of Technology, Wright-Patterson AFB, Ohio

6C "Higher Quality Through 'People in Quality—Quality in People'" — **English**
Eugene V. Grumman, chief engineer, Bullard Company, Bridgeport, Conn.
Moderator: David H. Shearer, manager, Purchasing Performance Evaluation Department, Chrysler Corporation, Highland Park, Mich.

1:30- 5:30 pm Plant Tours:
Beckman Instruments, Berkeley
Friden, Inc., San Leandro
Gerber's Products, Oakland

1:30- 2:30

6D "Defining the Quality Control Job" — **285**
Robert Schin, chief, QC Engineering Department, Western Electric Company, Allentown, Pa.
Moderator: R. S. Bingham, Jr., quality control manager, Carborundum Company, Niagara Falls, N. Y.

6E "Reliability in Communications and Administrative Applications" — **Parlor A**
Harry G. Romig, reliability director, Engineering Military Products Division, Hoffman Electronics Corporation, Los Angeles, Calif.
Moderator: L. J. Paddison, director of quality assurance, Sandia Corporation, Albuquerque, N. M.

2:15- 3:15

Insp. Wksp "Gage Repeatability" — **Concert**
Leon Bass
Moderator: R. Calvert Haws

7A "Power Characteristics of Control Charts" — **English**
Edwin G. Olds, professor of mathematics, Carnegie Institute of Technology, Pittsburgh, Pa.
Moderator: Martin A. Brumbaugh, director of statistics, Bristol Laboratories, Inc., Syracuse, N. Y.

7B "Life Tests — Some Practical Considerations" — **French**
Harold J. Davis, division reliability engineer, Industrial Components Div., Raytheon Co., Newton, Mass.
Moderator: Gordon H. Beckhart, coordinator quality engineering, Radio Corporation of America, Moorestown, N. J.

7C "Good Enough **Isn't** Good Enough" — **California**
Bernard I. Raysor, works manager, Harrison Radiator Div., GMC, Lockport, N. Y.
Moderator: J. H. Molnar, quality control manager, Houdaille Industries, Inc., Detroit, Mich.

VISIT EXHIBITS — **Rose**

2:45- 3:45

7D Panel Discussion: "Predicting and Specifying Reliability — Part I"
Moderator: James M. Bridges, director of electronics, Office of Director of Defense and Engineering, Department of Defense, Washington, D. C.
Nicholas T. Golovin, deputy associate administrator, National Aeronautics and Space Administration, Washington, D. C.
Charles J. Brzezinski, Inspection and Quality Control, Office of the Assistant Secretary of Defense (Supply and Logistics), Washington, D. C.

7E "Quality Control Programs Should Be Cost Reduction Programs" — **Comstock**
Harmon S. Bayer, Quality Control Consultant, Detroit, Mich.
Moderator: Bernard Hecht, Quality Control & Reliability Specialist, Los Angeles, Calif.

7F "Some Economic Aspects of Quality Standards" — **285**
Lawrance F. Bell, acting associate professor of industrial engineering, Stanford University, Stanford, Calif.
Moderator: Ralph D. Humphries, inspection supervisor, Cessna Aircraft Co., Wichita, Kans.

VISIT EXHIBITS — **Rose**

3:30- 4:30

Insp. Wksp "Use of Optical Comparators in Everyday Inspection" — **Concert**
Cliff Commeford, sales manager, Paul B. Slater Co., Los Angeles, Calif.
Moderator: R. Calvert Haws

8A "Mechanization, Quality Control and Automation" — **California**
A. W. Wortham
Moderator: Frank J. Sindelar, quality manager, IBM Corp., Poughkeepsie, N. Y.

8B "Solid Rocket Quality, Its Establishment and Control" — **French**
E. C. Gustley, manager, Quality Control Div., Solid Rocket Plant, Aerojet-General Corp., Sacramento, Calif.
Moderator: John G. Rutherford, assistant quality manager, Lear, Inc., Grand Rapids, Mich.

8C "Sampling Frozen Beef Using a Variable Sampling Plan for Percent Fat" — **English**
Gerald Desmond, quality control manager, Gerber Products Co., Oakland, Calif.
Moderator: Bruno A. Filice, food technologist, Filice and Perrelli Canning Co., San Francisco, Calif.

VISIT EXHIBITS — **Rose**

4:00- 5:00

8D Panel Discussion: "Predicting and Specifying Reliability — Part II" — **Gold Ballroom**
Moderator: James M. Bridges
Lt. Col. H. C. Metzler, chief of safety and reliability, Special Weapons and Ammunition Command, Picatinny Arsenal, Dover, N. J.
Capt. B. L. Lubelsky, Office of the Chief of the Bureau of Naval Weapons, Department of the Navy, Washington, D. C.

8E "Company Standards and Quality Control" — **Comstock**
Maj. Gen. Leslie E. Simon (ret), staff director of research, Carborundum Co., Niagara Falls, N. Y.
Moderator: Richard H. Ede, process metallurgist, US Steel Corp., Chicago, Ill.

8F "Automatic Production Recording—Yield—Quality Control" — **285**
James A. Curry, supervisor, Industrial Engineering Dept., Kaiser Steel Corp., Fontana, Calif.
Moderator: W. T. Rogers, product engineer, National Tube Div., US Steel Corp., Lorain, Ohio

8G "A Program for Defining and Controlling Visual Defects in a Multiplant Operation" — **Parlor A**
Eldridge E. Allen, manager, Quality Control Div., American Can Co., New York, N. Y.
"Quality Control of Visual Characteristics"
C. W. Carter
Moderator: Stanley B. Sherwood, Process Development Staff, General Motors Research Center, Detroit, Mich.

6:00 **Exhibits Close**

6:30 pm **ASQC Annual Banquet** — **Garden Court**

Hotel Sheraton Palace, San Francisco, California

THURSDAY, MAY 26, 1960

8:00- 9:30 **Registration**

9:00 **Exhibits Open** — **Rose**

9:30-10:30

Insp. Wksp "Non-Destructive Inspection Techniques Developed for Missile Evaluation" — **Concert**
J. H. Cusick, head, Physical Sciences Div., Quality Evaluation Lab., Naval Ammunition Laboratory, Concord, Calif.
Moderator: Ray E. Primmer

9A "The Technologies of Total Quality Control" — **Gold Ballroom**
A. V. Feigenbaum, Manufacturing Operations and QC Services, General Electric Company, New York, N. Y.
Moderator: W. Gordon Thompson, quality control engineer, Champion Paper and Fibre, Hamilton, Ohio

9B "Selection of Flavor Panels for Complex Flavor Differences" — **285**
Mae-Goodwin Tarver, research statistician, Research and Development Department, Continental Can Company, Chicago, Ill.
Moderator: David S. Chambers

VISIT EXHIBITS — **Rose**

10:00-11:00

9C "Quality Assurance for Reliability" — **Comstock**
C. W. Harris, director, Quality Assurance & Test Services, Lockheed Missile Systems Division, Sunnyvale, Calif.
Moderator: Richard P. Della-Vedova, manager satellite systems quality assurance and test services, Lockheed Missiles and Space Division, Sunnyvale, Calif.

9D "How Many Dollars Are There in Incoming Inspection Costs?" — **California**
Fred Ennerson, Jr., supervisor, Statistical Analysis Department, Hughes Aircraft Company, Tucson, Ariz.
Moderator: August B. Mundel, director of quality control, Sonotone Corporation, Elmsford, N. Y.

9E "Sampling Techniques for Corrugated Shipping Containers" — **French**
John S. Randall, assistant director of quality control, Anheuser-Busch, Inc., St. Louis, Mo.
Moderator: O. F. Hunzicker, division manager of quality control, Continental Can Company, Chicago, Ill.

VISIT EXHIBITS — **Rose**

11:00-12:00

Insp. Wksp "What Government Source Inspection Means To (and expects of) You" — **Concert**
E. J. Lancaster, chief quality control, Ballistic Missile Center, Inglewood, Calif.
Moderator: Ray E. Primmer

10A Panel Discussion: "Sampling Problems in The Metals Industry" — **Gold Ballroom**
Moderator: A. L. Raich, QC statistician, Colorado Fuel & Iron Corporation, Pueblo, Colo.
L. J. Barker, chief specification engineer, Kaiser Aluminum & Chemical Corporation, Oakland, Calif.
J. N. Berretoni, Quality Control Consultant, Shaker Heights, Ohio
J. Y. McClure, manager of quality control, Convair, a Division of General Dynamics Corp., Fort Worth, Texas
J. F. Occasione, staff metallurgical engineer, American Steel & Wire Division, US Steel Corp., Cleveland, Ohio

10B "Total Quality Control Through Reliability" — **285**
Frank M. Gryna, Jr., project reliability administrator, The Martin Company, Baltimore, Md.
Moderator: James R. King, senior staff engineer, AVCO Manufacturing Corporation, Wilmington, Mass.

11:30-12:30

10C "Progress in Professionalism" — **California**
Wyatt H. Lewis, QC Engineering Services, General Electric Company, New York, N. Y.
Moderator: William A. Golomski, director of operations research, H. J. Mayer and Sons Company, Chicago, Ill.

10D "The Analysis of Variations for Certain Physical Properties of Combed Cotton Yarns" — **French**
Dame S. Hamby, associate professor, School of Textiles, North Carolina State College, Raleigh, N. C.
Moderator: John H. Reynolds, statistician, Celanese Corporation of America, Rome, Ga.

10E "Production and Inventory Control of Telephone Handsets" — **Parlor A**
Irving Heitner, assistant superintendent of operations research, Western Electric Company, New York, N. Y.

1:30- 2:30 pm

Insp. Wksp "Gage Control in the Inspection Department" — **Concert**
Herman Karlebach, chief inspector, Omark Industries, Inc., Portland, Ore.
Moderator: R. Calvert Haws

11A "The Challenge of Reliability" — **Gold Ballroom**
William A. MacCrehan, Avionics Quality Control, Bendix Radio Division, Baltimore, Md.
Moderator: Robert Fitzgibbons, reliability engineer, Wayland Laboratories, Raytheon Manufacturing Company, Wayland, Mass.

11B "Application of OR to Spare Parts Provisioning" — **285**
Herbert W. Karr, manager, Material Management Section, Planning Research Corporation, Los Angeles, Calif.
Moderator: Acheson J. Duncan, associate professor, Johns Hopkins University, Baltimore, Md.

11C "Statistical Evaluation" — **Parlor A**
Paul S. Olmstead, consultant in engineering statistics, Military Systems Engineering, Bell Telephone Laboratories, Whippany, N. J.
Moderator: F. H. Hunsicker, plant manager, Continental Can Company, Pittsburgh, Pa.

VISIT EXHIBITS — **Rose**

2:00- 3:00

11D "Bad Data in Industrial Experiments" — **California**
Cuthbert Daniel, Engineering Statistician, New York, N. Y.
Moderator: J. Stuart Hunter, Mathematics Research Center, University of Wisconsin, Madison, Wis.

11E "The Military Quality Assurance Program in Clothing and Textiles" — **French**
Lt. Col. B. P. Coburn, Military Clothing and Textile Supply Agency, Philadelphia Quartermaster Depot, Philadelphia, Pa.
Moderator: Robert G. Mitchell, manufacturing manager, International Latex Corporation, Dover, Dela.

11F "Quality Control in the Brewing Industry" — **English**
W. H. Von Meyer, plant manager, Hamm Brewing Company, San Francisco, Calif.

2:45- 3:45

Insp. Wksp "Questions and Summary of Inspection Workshop" — **Concert**
R. Calvert Haws and Inspection Workshop Staff

12A "Management Science" — **Gold Ballroom**
J. M. Juran, Management Consultant, New York, N. Y.
Moderator: Leonard A. Seder, Quality Control Consultant, Malden, Mass.

12B Panel Discussion: "The Procurement Problem" — **Comstock**
Moderator: Thomas C. McDermott, chief quality assurance, Armament and Flight Control, Autonetics Division, North American Aviation, Inc., Los Angeles, Calif.
Milton R. Sumner, chief engineering reliability, Nortronics Division, Northrup Aircraft Corporation, Hawthorne, Calif.
William C. Hanna, chief quality control engineering, Nortronics Division, Northrup Aircraft Corporation, Hawthorne, Calif.

3:00 pm **EXHIBITS CLOSE**

Gordean Lee, Miss Hawaii

Program

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Mid-Pacific QC Conference

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Honolulu, Hawaii

MONDAY, MAY 30, 1960

8:00- 8:30 Registration

9:15-10:00 "Total Quality Control"
A. V. Feigenbaum, General Electric Co., New York, N. Y.
Moderator: C. E. Fisher, Bell Telephone Laboratories, New York, N. Y.

10:15-11:00 "Breaking the Management Barrier to Reliability"
J. Y. McClure, Convair, division of General Dynamics Corp., Fort Worth, Texas
Moderator: C. R. Burdick, Houdaille Industries, Inc., Huntington, W. Va.

11:15- 1:00 Luncheon

1:00- 1:45 "What Constitutes the Total Price of a Purchase"
P. Calvert Haws, Quality Control Engineers, Inc., Los Angeles, Calif.
Moderator: Allen Chop, Lockheed Missiles and Space Div., Sunnyvale, Calif.
"Optimum Factor Combination in Curing of Prestressed Concrete"
George McPherson, Transit Mix Concrete, Ltd., Honolulu, Hawaii

2:00- 2:45 "Evolutionary Process"
J. D. Hromi, US Steel Corp., Monroeville, Pa.
"Reliability and Non-Destructive Testing of Solid Propellant Rockets"
M. E. Liebman, Aerojet-General Corp.

TUESDAY, MAY 31, 1960

8:00- 8:30 Registration

8:30- 9:15 "An Evaluation of QC and Quality Costs"
A. W. Wortham, Texas Instruments, Inc., Dallas, Texas

9:15-10:00 "An Approach for Evaluating One-Shot Device Sampling Plans"
B. A. McDonald, Lockheed Missiles and Space Div., Sunnyvale, Calif.

10:15-11:00 "Reliability — Definition, Control and Improvement"
Bernard Hecht, Quality Control and Reliability Specialist, Los Angeles, Calif.
Moderator: H. H. Bogin, Parke, Davis & Co., Detroit, Mich.

11:15- 1:00 Luncheon
"Ammunition Depot QC and Reliability Problems"
Capt. B. L. Lubelsky, Bureau of Naval Weapons

1:00- 1:45 "Quality Evaluation of Fruit at the Cannery"
Paul Paperzak
"Models of Continuous Sampling"
Gerald J. Lieberman, Stanford University, Stanford, Calif.
Moderator: W. B. Thomas, Libby, McNeil & Libby, Honolulu, Hawaii

2:00- 2:45 "Surviellance of Stored Material"
Herbert K. Solomon, Stanford, University, Stanford, Calif.
"Monte Carlo Methods in Problem Solving"
Seiji Sugihara, Lockheed Missiles and Space Div., Sunnyvale, Calif.

WEDNESDAY, JUNE 1, 1960

Plant Tours: Hawaiian Pineapple Co.
Oahu Sugar Co.
Brownie's Perfume Factory

3rd ASQC

Workshop-Seminar

Management of Quality Control

SIR FRANCIS DRAKE HOTEL, MAY 26-28

SAN FRANCISCO, CALIFORNIA

Industry is giving Quality Control a great deal of emphasis because of its potential for improving product quality while increasing productivity and reducing related costs. This increased scope of quality control has multiplied the responsibilities of the Quality Manager. To help him fulfill his new role, the American Society for Quality Control will conduct a workshop-seminar on Management of Quality Control for the three days of May 26, 27 and 28.

What is the purpose of the workshop seminar? To explore in depth, tested methods of increasing the effectiveness of the quality control program in an industrial plant.

For whom is the program planned? For present and prospective Quality Managers. It is expected that the applicant will have reasonable familiarity with such standard texts as Grant, Feigenbaum, and Juran. To benefit properly from the seminar, the applicant should have a minimum of several years experience with major responsibility for quality.

Who will direct and conduct the program? The Director will be Paul C. Clifford, Professor at Montclair State College. Speakers and Discussion Leaders will include managers of outstanding quality control programs.

Registrants will be sent study materials and case studies prior to the conference. Registration is limited to 75 persons and is complete only on receipt of the registration fee of $100 which includes the cost of three lunches.

Your Registration will be acknowledged. A room reservation card for the Sir Francis Drake Hotel will be enclosed with the acknowledgment.

From 8:30 am on May 26 until 8:00 pm on May 28 registrants will have a full schedule, including evenings. The title WORKSHOP has been chosen deliberately.

Third ASQC Workshop - Seminar
American Society for Quality Control
161 West Wisconsin Avenue
Milwaukee 3, Wisconsin

Please make reservations for the third ASQC Workshop-Seminar on Management of Quality Control for the following man who satisfies the registration requirements as indicated in the announcement.

Enclosed is our check for $..... to cover..... registrants. (Fee—$100 per registrant.)

Name .....

Title .....

Company .....

Address .....

City.....**Zone No.**....**State**.....

NOTE: Additional registrations may be made by attaching a list to the above coupon. Please include necessary information for each registrant.

Exhibition Announcements

Booth 3

AMERICAN CYSTOSCOPE MAKERS, INCORPORATED

Featured in this display will be a varied assortment of the standard line of borescopes, a series which ranges from 0.090 inch outside diameter to 1¾ inch outside diameter and in working lengths from 3 inches to 45 feet.

The display will also include some borescopes made for use in applications requiring special features and construction. Such applications include the following:

Higher temperature ranges
Hazardous locations
Nuclear installations
Jet powered aircraft
Rocket motors

American Cystoscope Makers, Inc., will also exhibit a miniature lamp display.

Booth 5

THE LUFKIN RULE CO.

The Lufkin Rule Company will exhibit precision tools, dial indicators and tapes and rules.

Booth 6

ELLIOTT SERVICE CO., INC.

A *brand new* exhibit featuring:

HI-VISION QUALITY PROGRAM

Designed to secure and hold employee cooperation in the twin fields of quality improvement and waste reduction. A visual means of moving minds towards plant quality objectives.

MANAGEMENT INFORMATION

A weekly bulletin for Supervisors and Foremen. Designed to provide job help and develop leadership qualities. Includes "human relations" guidance and a practical approach to supervisory planning.

SUGGESTION SYSTEM SERVICE

Complete working material and equipment for operating a successful suggestion plan. Includes colorful, effective publicity for securing quality and quantity suggestions.

Booth 8

HMS TOOLS

Harry M. Smith and Associates will show a number of tool lines.

Included in their display will be the Cleveland Instrument Company, electronic indicators and roughness meter; National Electric Instrument Division Borescopes; Rahn Granite Surface Plates, parallels and angle plates; Swift and Anderson microscopes; Shinko's Precision Optical Shadowgraph Comparators; Micro-Vu Optical Comparators, and Stocker & Yale Optical Shadowgraph Comparators.

Booth 12

PENNOYER-DODGE CO.

PRECISION GAGES

This display will include thread plug gages, thread rings and set plugs, roll thread snap gages, pipe plug and ring gages, reversible thread gages, reversible plain plug gages, cylindrical plain plug gages, cylindrical plain ring gages, flush pin gages, special application gages, and methods of lapping gages.

Booth 24

QUALITY CONTROL COMPANY

DEMONSTRATION OF BLACK LIGHT INSPECTION SCHEDULED

Visitors to Booth 24 at ASQC's 14th Annual Convention and Exhibition will have an opportunity to see a dramatic demonstration of one of the newest inspection techniques which involves the use of black light.

The growing use of liquid and gaseous oxygen made it imperative to develop a fast, safe and reliable test to assure contaminant-free parts and this method has proved itself excellent on all counts. The demonstration will show the inspection for cleanliness and the checking of printed circuits to reveal flux contamination. Black light is also used to examine circuit assemblies after the protective coating has been applied to be sure the potting has been done efficiently and completely.

A Blak-Ray B-100 Fixture manu-

SPECIAL FEATURE

First Annual

INSPECTION WORKSHOP

- Applications of quality control to everyday inspection problems
- Designed for inspectors and others who need practical help
- An extra series of the Convention sessions
- Runs all three days of the Convention
- For complete program see sessions labelled **Insp. Wksp.** on pages 50-52.

factured by Ultra-Violet Products, Inc., of San Gabriel, will be used and visitors will see how fluorescence reveals many hydrocarbons and other contaminants in addition to its well known uses in dye penetrant inspection for cracks.

Demonstrated vividly will be Blak-Ray's ability to locate possible causes of trouble before they have time to do harm. Various contaminants and foreign substances fluoresce brightly and actually call attention to their presence. William Ferguson, General Manager, Quality Control Company of Los Angeles, will conduct the demonstrations.

The Quality Control Company booth will also feature the Height Gage Scope for surface plate work, Riehle Portable Rockwell Hardness Tester, Nu-View Bench Optical Comparator, Unitron Toolmaker's Microscope, Precision Tools and Inspection gages, Profilometer for surface roughness, and the Bausch & Lomb StereoZoom Microscope.

Booth 29

OWENS-ILLINOIS

This Exhibit will not feature products at the ASQC 14th Annual Convention and Exhibition.

The booth will show a schematic layout of a glass container plant, with the inspection stations and other quality control checkpoints indicated thereon. Our theme is "Total Quality Control — Raw Materials to End Use."

The display is used in our salesman training program, to acquaint them with the many safeguards that assure our customers of receiving only the highest quality containers.

Booth 34

THE L. S. STARRETT CO.

This exhibit will display a general assortment of mechanic's hand measuring tools, precision instruments, and several dial bench gages and dial indicators.

Also displayed will be many new tools which have recently been added to the Starrett line. Among these will be the No. 123 Satin Crome Venier Caliper; No. 254 Satin Chrome Master Vernier Height Gage, No. 256 Disc Micrometer, No. 486 Blade Type Micrometer, No. 443 Half Base Depth Gage, No. C183 and No. C493B Satin Chrome Protractors, No. C359 Satin Chrome Protractor, Combination Squares and Sets with Satin Chrome Protractors and Blades, an assortment of new Micrometer Heads which are now widely used in the electronics industry and our new Series of No. 84 Dial Bore Gages.

Catalogs and circulars will, of course, also be available to those visiting the exhibition area.

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See Us in booth 12 at the 14th Annual ASQC Convention and Exhibition where we will display our:

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- Thread Rings & Set Gages
- Roll Thread Snap Gages
- Pipe Plug and Ring Gages
- Reversible Thread Gages
- Reversible Plain Plug Gages
- Cylindrical Plain Plug Gages
- Cylindrical Plain Ring Gages
- Flush Pin Gages
- Special Application Gages
- Methods of Lapping Gages

BOOK REVIEWS

W. D. Baten, Editor

26 University Drive, East Lansing, Mich.

MODERN STATISTICAL METHODS — DESCRIPTIVE AND INDUCTIVE by Palmer O. Johnson and Robert W. B. Jackson, Rand McNally & Co., Chicago, Ill. 1959, ix-514 pages, $8.00. Reviewed by W. D. Baten, Michigan State University, East Lansing, Mich.

Chapter Two contains material on the binomial, Poisson, normal, negative binomial, rectangular distributions, means of samples and variances of samples. The next two chapters present tests of statistical hypotheses, tests of significance between proportions and between proportions when there is dependence. This last subject is well explained with essential details for carrying out such tests. This part, not given in many statistical texts, will furnish the reader with interesting subject material. Chapter Five treats of applications to Chi-square for testing various hypotheses such as: determining whether or not an observed frequency distribution can be graduated by a given distribution, testing for independence between two classifications, testing between correlated proportions and testing results for various types of questionnaires.

The following chapter shows how to carry out tests pertaining to sample averages for various assumptions about the standard deviations, the t-distribution and significance of differences between sample means when there is correlation. Chapter Seven contains a good discussion on the F-distribution and points out when to use a one tail test and a two tail test, explains Bartlett's test for determining whether several variances are results of sampling from one parent and discusses the use of variances in the test of goodness of fit. Chapter Eight exhibits analysis of variance in which the following are explained in many details: one-way, two-way and three-way classification designs, fundamental sums of squares, identities pertaining to sums of squares, mathematical models, designs where the "cell" numbers are equal and not equal. The tests and various hypotheses for different classifications are carried out in many details which form the meat of this portion of the book. Methods for calculating sums of squares pertaining to the main and the interaction effects are given in precise form together with appropriate F-tests. The authors did a good job in this chapter.

Chapter Nine presents some parametric tests such as the sign test, the median test, Wilcoxon T-test, Marshall test, Pitman W-test, H-test, test of independence, the test of randomness and the Rank correlation coefficient is also presented. These will introduce the reader to test material that is gradually getting into modern statistical texts. Chapter Ten treats of problems of estimation in which is described the characteristics of good statistics but little use is made of these four characteristics in the tests that follow. Material containing the estimation of the population mean for known and unknown population variances, differences between two population means when the population variances are known and unknown, estimation of individuals examination scores, confidential intervals for F when the samples are independent and dependent, confidence interval for a proportion, confidence interval for the correlation coefficient and confident intervals for the median and centiles.

Chapter Eleven contains material on linear regression, linear correlation, correlation ratios, tetracorrelation, testing for significant regression coefficients, biserial correlation coefficient, testing for linearity. The test for linear regression is interesting and well explained. This is followed by a chapter which treats of multiple regression, multiple correlation, partial correlation, nonlinear regression, fitting orthogonal polynomials to data showing the reduction of the standard error of estimate for each added term. Chapter Thirteen contains material on the analysis of covariance in many of its details, regression and the Johnson-Neyman method including single matching variables, two matching variables and the generalized distant function and the discriminate function.

The appendix contains tables concerning the area under the normal curve, Chi-square, t-distribution, F-distribution. The book is well written and contains a great deal of information.

Demonstrate and Teach the Use of Statistics . . .

. . . with the Process Simulator—an electrical analog of an industrial process. Provide dramatic proof of the effectiveness of statistics.

Simulate a desired process with the controls on the rear face of the instrument. A wide variety of functional relationships — linear or curvilinear, positive or negative — can be easily programmed. Select the desired degree of automatically created process variation and degree of bias between simulated machines or operators. Interaction of the main effects also possible.

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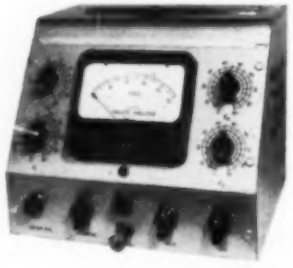

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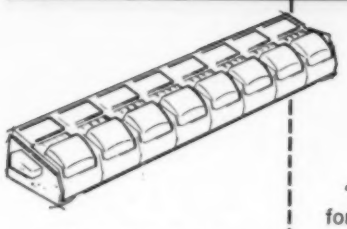

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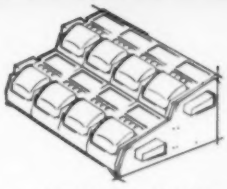

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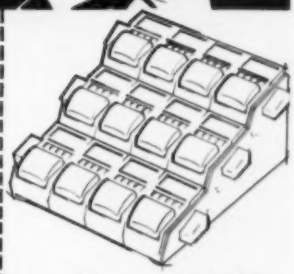

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What's New?

ROY A. WYLIE, *Editor*
Ampex Corporation

P-5-1—The Gerbet Torsiometer for testing instrument hair springs for torque is now available. No master spring is required to check the torque, for the instrument operates on the "balance" principle with the spring "zeroed in" then loaded up to 100 degrees. By moving the milligram weight, a direct reading is made on the millimeter scale. Milligram weights determine the calibration accuracy. Movement of the pivot at point of contact is minute as the arm moves only in a 5 degree arc, thus reducing friction to a minimum. The hardened and polished pivots are supported in "V" jewels, mounted in a rugged poising block.

* * *

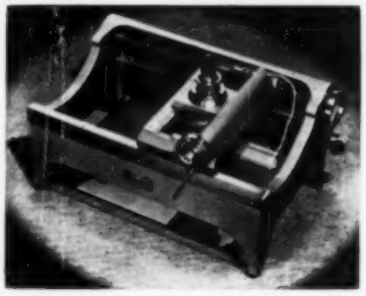
P-5-2—A new Electro-Autosizing electronic comparator for high precision checking and inspection work, calibrating gauge blocks, masters, etc., checking parallelism, ball sphericity and for checking production runs, has been announced. In addition to basic accuracy, several major advances have been made toward the elimination of variations caused by atmospheric conditions. The EAM Sensitron features a new patented double capacitance gauge head, designed to eliminate electronic drift regardless of changes in the atmosphere or fluctuations in the line voltage. The manufacturer guarantees stability within one millionth of an inch throughout the day. The gauge stand for the EAM Sensitron is of light weight construction and is designed to control the direction of thermal change within 0.000004 inches.

* * *

P-5-4—Because it can be fitted with an electromagnetic or chain clamp, the British made Indentometer (Portable Hardness Tester) can make Rockwell tests in the factory or the field that are impractical or impossible with ordinary models. An hydraulic pressure unit applies a minor load of 10 kg and a major load up to 150 kg for normal Rockwell testing procedures. Readings are direct in Rockwell A, B, or C scales. Versatility of the Indentometer is obtained by the use of optional electromagnetic or chain clamps. Part size and configuration are not limitations when these clamps are used. The electromagnetic clamp can be applied to flat as well as to curved surfaces. The chain clamp enables the tester to be mounted against large work, ferrous or nonferrous, since chain length can be as required. Standard equipment includes a cone diamond penetrator (120 degree angle with spherical tip), ball penetrator (1/16" diameter steel ball), a standard C-clamp (5-3/4" wide by 5-1/4" deep), flat and "V" anvils, and a test block. The standard clamp can be provided with a quick-release cam mechanism to quickly check identical parts. Weight of the standard instrument is only 18 lbs.

* * *

P-5-5—Of interest to Quality Control departments in larger plants is the Friden Collectadata data collecting system. It is a system of code reading and code punching units to facilitate the collection of data at a central processing point from various points of origin. Collectadata is engineered for internal systems whereby information must be channeled to and accumulated at one location from many or widely separated sources. The stations may be strategically located in shops, production lines, zones, departments, offices or wherever data may originate. Data that is reproduced from the Collectadata receiver and punched tape can be converted to tab cards and fed directly to computers. However, large scale computers are not always necessary for practical use of a Collectadata system. The system consists of one or more transmitters and a receiver. The transmitters, with edge card readers, will automatically read and transmit coded information to the central location where it is accumulated on punched tape on a Collectadata receiver. These units are provided with eighteen dials which may be adjusted manually for adding valuable numeric data. The second version of the transmitter is the tab card unit which will read tabulated cards punched with Hollerith code. Other features are the same as the edge card model. The Collectadata receiver is an eight-channel tape punch which will accept coded data from multiple transmitters with either edge card or tab card readers. A Time Code Emitter can be provided for automatic digital readout to record the time of transmission.



P-5-7—A new Ealing two dimensional microscope priced at under a thousand dollars features the following specifications: scans 20 x 10 centimeters, reads direct to .01 mm, reading accuracy ± .01 mm, two scope objectives, 5x 20x, working distance 4 cm. The instrument measures both opaque and transparent objects and with minor adjustments, can be placed directly on the object to be measured.

* * *

P-5-6—Newly designed accelerated corrosion testing equipment has been announced by Industrial Filter & Pump Mfg. Co. The salt fog, humidity test cabinet is a self contained unit requiring no auxiliary tanks, mixers, pumps or apparatus. All components are contained in a "packaged" unit. Designed in sizes to accommodate test specimens, panels or entire product in simulated environments, the cabinets meet requirements of most federal and commercial test specifications. Standard size or special size test cabinets to conduct "Cass", Corrodkote and other accelerated environmental tests requirements are designed and built to rigid specifications. Additional information on specifications, sizes, dimensions, and performance are available from the manufacturer.

* * *

P-5-12—The development of an Electronic Auto-collimator capable of measuring the tilt of a reflective surface with respect to the Auto-Collimator axis has been announced by Keuffel & Esser Co. The instrument may be used for checking flatness of surface plates, for monitoring drift of gyros, for checking straightness of machine tool ways, and for checking run-out of precision bearings. The Electronic Auto-Collima-

HOW TO MEASURE SURFACE ROUGHNESS with New METROsurf*

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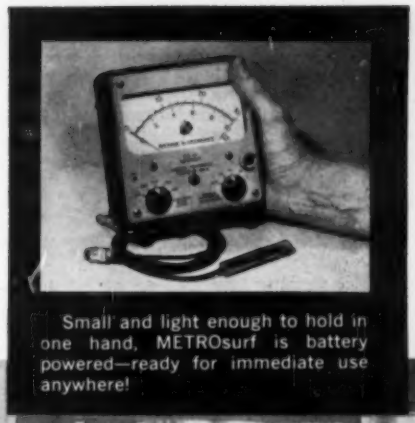

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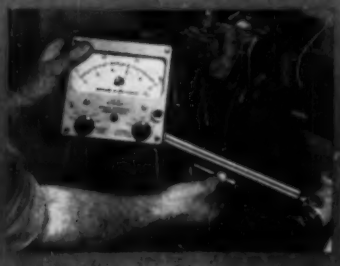

Big dial shows average surface roughness in seconds right at your machine . . . without lifting or removing your work.

Measure any surface however complex—ID, OD, even gear teeth. Reach way into small, nearly inaccessible surfaces or measure across several feet of material on a production line.

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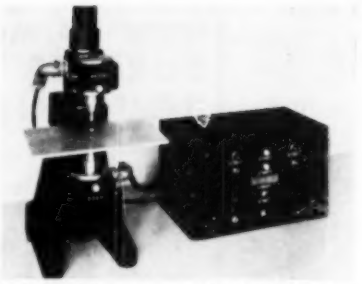
CONTROL

tor reads angles directly to a sensitivity approaching 1/50 of a second. The sensing unit transmits the signal (angular deviation) through the amplifier to the remote indicating unit by cable. A chart recorder can be used in addition to the indicator to provide a permanent record, or the signal can be fed into a servo-mechism or computer. The Electronic Auto-Collimator consists of a sensing unit, a power amplifier, and an indicator. The sensing unit has an indicating range of 50 seconds (plus or minus 25 seconds), with a working distance of up to 30 feet between sensing unit and reflecting surface. Response is 20 milliseconds and there is a built-in optical wedge for checking calibration of indicator. Drift is less than 1 per cent in 24 hours after initial warm-up. The sensing unit is approximately 9 lbs. in weight, with an overall length of 17-1/2 inches. The power amplifier's characteristics include a required power input of 115 volts, 60 cycles, 150 watts. Power output is suitable for chart recording and, after amplication, for servo-system feed. Output voltage is plus or minus 15 volts for the full scale range. Output impedance is approximately 600 ohms; one milliampere maximum. The indicator's sensitivity selection has a 3-position switch with ranges of plus and minus 1, 10 and 25 seconds. Its scale is graduated to read directly in angular units. Electronic damping with 2 second time constant is provided. Ten feet of cable connect the sensing unit to the power amplifier and the power amplifier is connected to the indicator by 50 feet of cable. This length can be increased to 2,000 feet on special order. Electronic Auto-Collimators with special ranges and sensitivities can be supplied on special order.

* * *

P-5-9—A new high efficiency, self illuminated 7 power inspection magnifier which enables faster, easier, more revealing examination of surfaces for general industrial use, has been introduced by Litho Research, Inc. The new device, called Micro-Lite, has an optical system featuring double lenses 1-3/16 inches in diameter which give a brightly lighted, needle sharp image over the entire field. Interior surfaces of lens housing are white enameled to provide the highest level of shadowless light reflectance from the surfaces under examination. A detachable black enameled base plate has a 1 x 1 inch opening with white line edge rulings in both inches and millimeters. Removing the base gives a 2 inch diameter circular field. Overall length of the Micro-Lite is 7 inches, with magnifier head 2 inches in height. The Micro-Lite is priced at $9.95 complete with two standard flashlight batteries.



P-5-10—The new model VDR is the latest addition to the line of Carson-Dice Electronic Micrometers and is the first opposed head measuring device permitting pressureless measurement from two sides to the centerline of a fragile or compressible part. Opposing micrometer tips may be zeroed against each other at a selected reference position or at the anvil surface. Set-ups can be made using dummy parts and carriages which are placed between two micrometer tips at the desired point of measurement. Electronic controls bring upper tip downward to touch top of part, lower tip upward through hole in lower anvil to contact bottom. Measurements to 20 millionths of an inch are automatically displayed on easily read counters.

* * *

P-5-8—Complete equipment and instructions needed to take liquid samples from a pressurized system for determining particle contamination are provided in a new kit developed by the Millipore Filter Corp. Key component in the "Bomb" sampling kit is the Millipore Field Monitor, a plastic filter holder containing a Millipore filter disc which provides a closed system of sampling, preventing incidental contamination. Monitors are supplied sealed, clean and ready to use. They are disposable, leaving nothing to clean up after use. The Bomb Sampler is "plugged" into the system to be analyzed. The operating pressure of the system forces a representative sample of liquid through the Millipore filter in the Field Monitor into a graduated polyethylene bottle attached to the Bomb. All particles in the sample will be retained on the surface of the filter within the Monitor. After sampling, the field monitor is disassembled to expose the Millipore filter for microscopic examination and counting of particles. Alternatively the filter disc may be scaled for radioactivity, or weighed to determine the total weight of contaminant. By providing permanent "quick-release" fittings at sampling points on each system, a single Bomb Sampler will serve a large number of systems in a given area. Applications include the analysis of liquids in aviation fuel systems, hydraulic test and flush stands, water injection systems for secondary oil recovery, and nuclear moderator and cooling loops.

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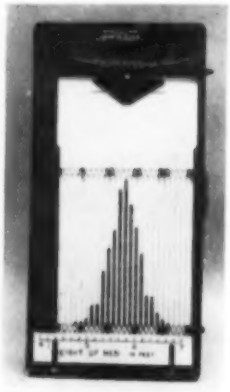

The Quincunx is a must for presentation of basic quality control principles. Demonstrates visually to your audience how a Normal Distribution pattern is formed. Also demonstrates how various Non-Normal distributions are formed.

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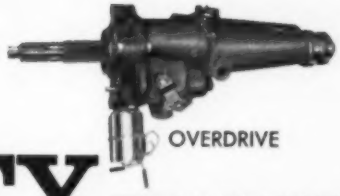

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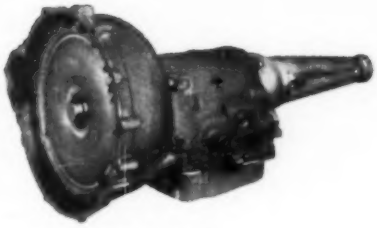

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- ★ Distribution and Probability Charts In Trouble Shooting

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Muncie, Indiana

P-5-3—New job standards templets developed by Titmus Optical Company for use with the T/O vision tester, permit the user to grade instantly each employee's visual performance, in relation to the visual needs of six principal job categories. The complete set of templets cover clerical, inspection, mobile, machine, unskilled and skilled workers. Each template is a clear acetate overlay. The test record form furnished with the T/O Vision Tester, when complete with results of the employee's test, is placed under the templet. Instantly one sees whether the employee has passed or failed to meet the visual standards for his particular work. The job visual standards have been derived experimentally and where desirable they may be modified by the doctor to meet specific local needs.

New Literature Available

L-5-1—Two portable thickness testers, Audigage Model 5 and Model 6 are detailed in an 8-page bulletin in A-200 available from Branson Instruments Inc. These ultrosonic gages permit measurement of thickness from only one side of a wide variety of materials metal, glass, plastic—by relating a variation in thickness to the change in resonant frequency.

L-5-2—The Johnson Gage Company, manufacturers of precision thread comparators and gages, have published a comprehensive new catalog on their complete line of Ring-Snap, Roll-Snap Comparators. The new catalog contains, in addition to the complete Johnson line, much essential technical information, including recommended gaging procedures, some of which have never before been published.

* * *

L-5-3—Now available from the Geartner Scientific Corporation is a 28-page bulletin describing the complete line of Gaertner Optical and Instrument Benches. The new bulletin gives general features, descriptions and specifications for Lathe Bed Type Benches, Double Rod Benches, Single Rod Benches, and Accessories.

* * *

L-5-4—Sheffield Precisionaire Gaging, a 50-page book, is available to AQC readers. Written especially for Quality Control Gage Designers and Tool Engineers, it describes in nontechnical language, how to select the right amplification for the gaging job, when to use long range air gauges, the advantages and principles of air gaging inside diameters, outside diameters and other geometrical conditions, and many other facets of dimensional control.

L-5-5—A new bulletin on surface finish measurement with a Profilometer has just been published. It contains illustrations showing a variety of Profilometer combinations for measuring the surface finish of almost any production surface, and shows typical applications in some well-known plants. It illustrates normal range of roughness readings, and what happens to surfaces when cutting tools begin to get dull.

* * *

L-5-6—A new booklet on screw thread root characteristics has been published by Standard Pressed Steel Company. This is the area of most tension bolt failures and has been virtually ignored in major screw thread standards. The root should be larger, rounder and better controlled than it is on most industrial and aircraft fasteners today according to the 20-page pamphlet on the subject. The difference between a good and bad thread root—perhaps as little as 0.002 inches in radius—may literally waste half the design load or 99 percent of the fatigue life of an otherwise sound fastener. The pamphlet provides both designers and fastener users with a thorough review of the situation, including a listing of the basic criteria for a good thread root; a comparative analysis of three widely used thread forms, including data on relative performance in tension-fatigue and at temperature; a complete specification for a large, round root radius that has been introduced in the aircraft and missile field; a capsule history of the evolution of this critical design aspect of the thread; an informative preview of some new large radius screw thread standards that are expected in the near future.

* * *

L-5-7—A new illustrated bulletin describing the RF Bridge, Type B-601 has been issued by Wayne Keer Corp. Bulletin No. WK B 601 describes features, specifications, principle of operation, performance, and gives applications of the Wayne Kerr B-601 multi-ratio bridge, a highly accurate transformer ratio-arm bridge designed for resistance, capacitance and inductance measurements over a wide frequency range; 15 Kc to 5Mc.

* * *

L-5-8—A combination catalog and price list on precision accessory equipment and special services for granite surface plates is available from Herman Stone Company. The bulletin describes and illustrates a complete line of accessories including "Air Lift" angle blocks and riser blocks, straight edges, parallels, toolmakers' flats and many others. Also described is the special field inspection service for checking surface plate accuracy and a relapping service for restoring the accuracy of worn surface plates.

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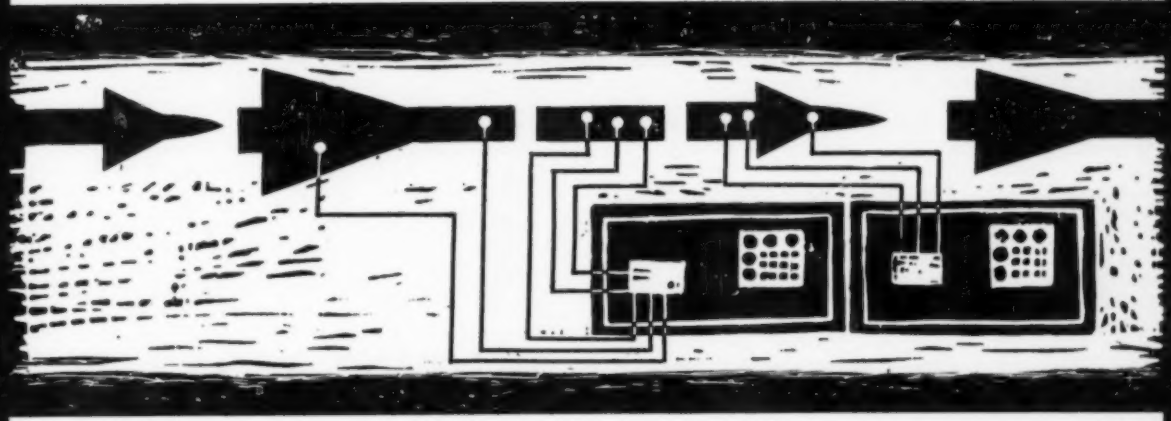

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section briefs

ALBUQUERQUE . . . The first dinner meeting was held at the Sandia Base Officers' Open Mess. The meeting was very well attended and the steak dinner elicited favorable comment from a large number of attendees. After dinner, the gathering retired to the comfortable surroundings of the Mesa room, where R. A. Wylie, QC manager, Instrumentation Division, Ampex Corp., Redwood City, Calif., gave an extremely interesting talk on "The Repeatability of Gaging." Mr. Wylie's talk evoked a large number of provocative questions during the discussion period. As is customary, Mr. Wylie received a small personal gift as a momento of his visit to the section.

On May 9, the Albuquerque section will hold its annual banquet. Members and their wives attend this affair to enjoy a fine dinner and listen to a well-known resident speak on a non-technical, general interest subject.

AKRON-CANTON . . . An interesting trip was enjoyed by section members at the February meeting when a plant tour was conducted through the Firestone Tire and Rubber Company of Akron. Approximately 40 members braved the weather and appeared for the dinner and tour.

An executive committee meeting was called by chairman Bob Dorn to make plans for the coming year. A nominating committee was appointed to prepare a list of candidates for offices for 1961-62.

ALBANY . . . E. B. Godsey, Collins Radio Co., spoke on "The Overlooked Techniques of Properly Selecting the Sample," at the meeting Feb. 11. As a general rule, insufficient consideration is given to the selection of sample sizes. By proper use of information obtained from sampling experimentation, major reductions in sample sizes can be achieved. Mr. Godsey discussed the techniques for using this information to reduce inspection costs without sacrifice of validity and accuracy. His talk led to a spirited question and answer session.

ALLENTOWN-BETHLEHEM . . . Our February meeting was held at the Hotel Traylor, as usual. The main speaker was Harry G. Harding, IBM Corp. Mr. Harding is in charge of IBM's Commercial Quality Group and used his experiences in that group to present a very interesting talk on "Vendor Quality Rating Procedures," as developed and utilized at IBM.

Another pre-meeting clinic was held, and again it was very well attended and received. Section chairman Ken Stephens, Western Electric Co., discussed "Graphical Analysis of Means — Attributes Data."

Both Bob Schin and Miss Bonnie Small of the Allentown plant, Western Electric Co., are getting around lately, speaking in all parts of the country. We're looking forward to a June meeting in the form of a Ladies' Night. Both will be firsts for this section and plans are just about set for a big night.

James W. McRae

It is with deepest regret that the Albuquerque section reports that James W. McRae, 49, a vice president of A. T. & T. Company since October, 1958, died Feb. 2, while enroute to the operating vice president's conference at a New York City hotel. Mr. McRae was coordinator of defense activities for the Bell system.

BALTIMORE . . . F. Caplan, Jr., QC manager, Westinghouse Electric Corp., Blairsville, Pa., was our speaker at the February meeting. He explained to an audience of 50 members and guests the application of statistical QC techniques to job shop operations.

The first of three reliability seminars was held at Morgan College. Mrs. Naomi McAfee of the reliability engineering group, Westinghouse Air Arm, Baltimore, Md., spoke on "Reliability — the Problem."

T. A. Simonds, quality engineer of the Martin Co., discussed life testing at the March meeting.

BATTLE CREEK-KALAMAZOO . . . In spite of the worst snow storm of the year on Feb. 25, Henry Hull, research engineer, R. R. Donnelly & Co., Chicago, Ill., had a good audience for his talk on "Steps in Designing an Experiment." His talk was well received as indicated by the many questions. Jim Monk arranged and guided us through a plant tour of the Eaton Mfg. Co. Pump Division before Mr. Hull's talk.

Diplomas and certificates of attendance will be distributed to 25 members of the intermediate QC work shop April 26. Some of the members will have driven as much as 50 miles to attend class.

On May 19th, we'll have our 3rd Annual Ladies' night with dinner at Jack Howard's Escape in Battle Creek. The speaker will be Howard Le Violette, State of Michigan Alcoholic Beverage Tester. His talk will be "Quality Control with Staggering Results."

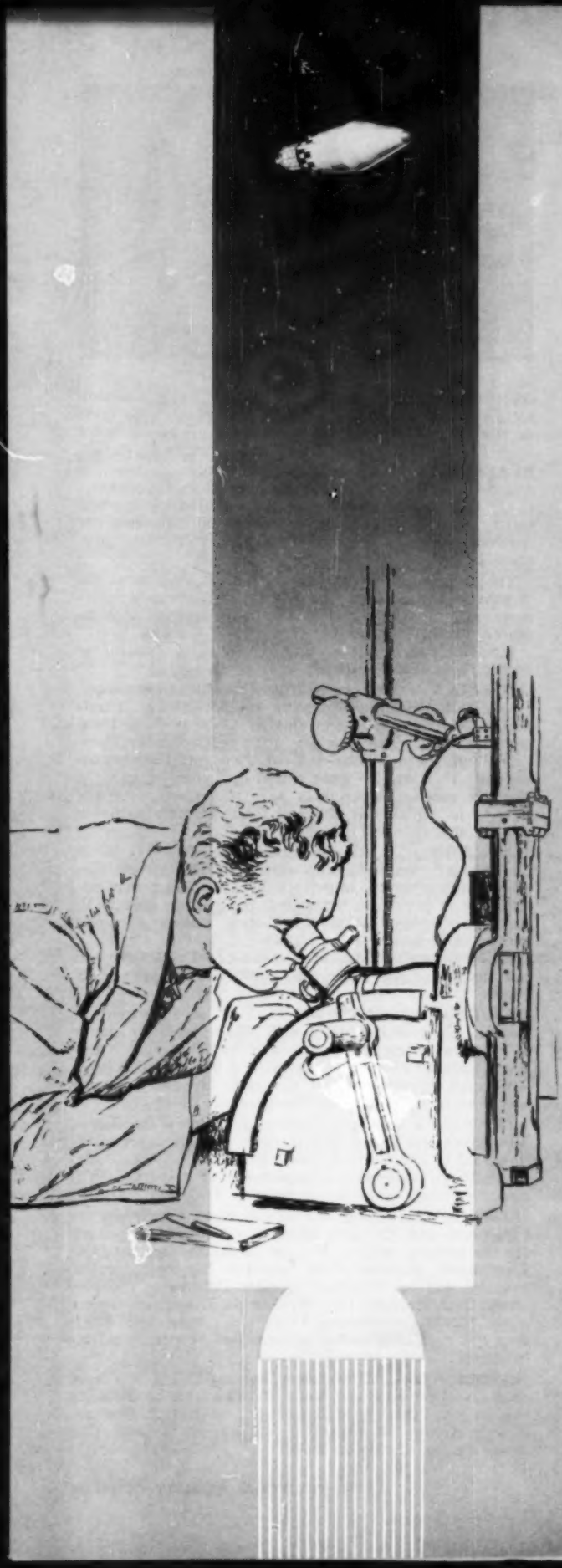
BINGHAMTON . . . Members and their wives heard the chancellor of the University of Buffalo speak on "The Next 100 Years," at the joint meeting with the Southern Tier Technical and Engineering Council. The dinner meeting was attended by 450 persons.

The technical study program in January on "Short Cuts to Significance Tests," proved a big success. Stan Rogge gave a lecture and conducted a practice session on very useful, yet simple techniques.

Members in the Central New York area should reserve Saturday, April 30, for the joint Binghamton-Corning Elmira One Day QC Clinic to be held at Cornell University. The program will consist of a 6-session technical program, and a concurrent 6-session general and administrative program. Speakers and topics will be announced in a forth-coming clinic flyer.

BOSTON . . . Dorian Shainin, vice president and director of statistical engineering, Rath and Strong Consultants, Boston, Mass., spoke to a few more than 100 of us "Qualitonians" at our "home" in the MIT Faculty Club Feb. 11. "Special Process Studies," was the subject. The audience was attentive and the remarks to this reporter as enthusiastic as usual — Dorian has never exhausted his fund of QC "Pearls" (and illustrative tales) in all the years he has returned to us.

Nominations have been made and ballots are in the mail (from and to David Harrington, our retiring secretary), and the final accounting has been reported. Officers nominated by the committee (which is composed of Harry Duane, General Electric Co., Lynn, Mass., section past chairman; Harold Davis, Raytheon, Newton, Mass.; and Frances Hermann, A. D. Little, Cambridge, Mass.) were William A. Donovan, B. F. Goodrich, Watertown, Mass., to be chairman; Bernard J. Goldsmith, Northeastern University, Boston, Mass., to be vice chairman; George F. Mason, Hersey Mfg., Dedham, Mass., to be treasurer, and Francis B. Kilduff, Jr., Instrument Development Laboratory, Attleboro, Mass., to be secretary.



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CHARLESTON . . . "Operations Research in Business and Industry," was the title of a paper presented jointly by J. L. Williamson and J. P. Kelly, both of Union Carbide Chemicals, at the meeting Feb. 26.

Despite the weather being out of control, opposition from Engineer's week activities, and championship basketball, an enthusiastic crowd was in attendance.

CHICAGO . . . Despite the poor weather, the turnout for the February dinner meeting was excellent.

John Jasch, purchasing agent, Victor Adding Machine Co., expressed his views about quality control. He also volunteered helpful advice on procedures and approach to suppliers regarding quality standards. A very spirited discussion followed his presentation.

Dinner reservations for the May meeting may be made by contacting W. Shawinski, Illinois Testing Lab. Inc., telephone WH 3-1331.

CINCINNATI . . . At the meeting Feb. 17, Winston C. Dalleck, Consultant, McKinsey and Co., Chicago, Ill., discussed "Monte Carlo Applications," as applied to solving business problems. The talk included defining the game, determining probability of events happening and a set-up to obtain randomization. A most enjoyable evening was had by those attending.

The film, "Holiday in Hawaii," was presented by W. E. Mitchell, United Airlines, Dayton, Ohio.

On Feb. 29, the Cincinnati section participated with the American Chemical Society in the sponsorship of a joint Symposium "Statistical Methods in the Chemical Industry." Harry Smith, Proctor and Gamble Co., and Ralph Bradley, Florida State University, provided an interesting evening.

The May 18 meeting will be the annual joint section meeting with the Hamilton-Middletown section and will be held in Cincinnati this year. Gordon Thompson, Hamilton-Middletown section, will discuss "Professionalism in ASQC" at the coffee talk.

CLEVELAND . . . An exceptionally large turnout was on hand to hear Father Henry Birkenhauer, John Carrol University, Cleveland, speak on "Quality Control in the Antartica." Father Birkenhauer described in a most interesting way the uses that he had made of QC during his stay at Wilkes Station, Antartica. Colored slides were also shown which described, as no words could, his year's stay in Anarctica.

Cleveland section members are looking forward to the return of William Pabst on May 6. Mr. Pabst, who was here several years ago, is returning to speak on "Mobilizing Statistical QC for the National Economy." With the high percentage of defense and government contracts in this area, this talk should prove to be one of the most interesting talks of the season.

COLUMBUS . . . W. E. Barker, Jet Engine Department, General Electric Co., Cincinnati, addressed our Feb. 17th meeting at Westinghouse Electric Corp. Mr. Barker's talk on "Organization Quality," covered the organization and operation of the QC function at the Jet Engine plant of the General Electric Co.

The May 18 meeting at 7:30 p.m., will be a plant tour of the Western Electric Co., which is one of the newest members of our community. We will have a chance to see all of the various products and techniques employed by the plant, which are entirely new to this area.

DALLAS-FORT WORTH . . . Program chairmen for the four Texas sections met in San Antonio on Feb. 20, to plan for eight circuit speakers to visit the four Texas sections during the 1960-61 year. An informative program was planned which took into consideration the needs of the sections. The San Antonio section sponsored this meeting. The South Texas section's program chairman will obtain confirmation from the speakers which have been agreed upon.

Carl M. Schwalm, TEMCO Aircraft, Grand Prairie, Tex., spoke at the regular monthly meeting Feb. 25. He brought a very interesting talk on "Quality Control's Responsibility in a Weapon System Reliability Program."

DENVER . . . Charter members of the Denver section were recently awarded plaques in appreciation for their service to the Denver section. These members were Dale L. Lobsinger, A. L. Raich, and Charles F. Weller.

EVANSVILLE-OWENSBORO . . . The February meeting was held at the Shady Rest Restaurant in Owensboro. L. J. Smith, manager, industrial engineering department, Mead Johnson & Co., Evansville, Ind., was the speaker. Mr. Smith presented a very interesting program on "Work Sampling."

The annual Ladies' Night will be held May 14, at the Westhaven Gun Club, Evansville, Ind. We are quite privileged to have Gayle McElrath, University of Minnesota, as the speaker for this special evening.

Mr. McElrath's subject will be "Quality Control — Woman's Oldest Weapon."

GEORGIA . . . Clarence R. Burdick, assistant manager, Huntington Division, Houdaille Industries, Inc., Huntington, W. Va., spoke on "Quality Control — A Management Tool." The talk was followed by many questions from the industrial engineers and production men present. This was an exceptional opportunity, and the Georgia section appreciates this prominent company helping to explain the progress made through applying quality control to management problems.

HAMILTON . . . At our meeting of Feb. 11, K. S. Kretschmer, mathematical economist, Marketing Research Department, Imperial Oil Ltd., Toronto, Ont., spoke on "Operations Research." His address clearly illustrates the application of statistics, mathematics and economics in business and industry. L. Marzec, Canadian Westinghouse Co., Ltd., will speak on "Reliability," at our meeting of May 12, instead of March 10 as previously reported.

HAMILTON-MIDDLETOWN . . . A huge turnout at the January meeting heard A. V. Feigenbaum, manager of manufacturing operations and quality control services, General Electric Co., present a talk on "The Road Ahead for Quality Control." Guests for the evening were members of the Hamilton Management Club.

Many members of the Cincinnati section were also in attendance, including Bill Barker, district representative, and H. Davis Birch, executive director, ASQC. Mr. Feigenbaum stressed the importance of using QC in a manufacturer's plans for competing in world markets.

The May 18 meeting will be sponsored jointly by the Cincinnati and Hamilton-Middletown sections. Speaker for the evening will be William E. Smith, foreman, QC department, National Cash Register. His topic for the evening will be "Practical Quality Control at the National Cash Register Co." W. Gordon Thompson, supervisor, statistical services, Champion Paper and Fibre Co., will present a coffee talk entitled "Professionalism in ASQC."

HARRISBURG . . . The dinner meeting Feb. 3, was held at the Yorktowne Hotel, York, Pa. The topic of the Buzz session was "Quality of Inspection," with J. T. Skelton, superintendent of inspection, Caterpillar Tractor Co., York, Pa., as discussion leader.

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Mr. Skelton outlined briefly what was meant by quality of inspection and the various factors that contribute to it. Each table was assigned a group leader to act as moderator. Some of the problems or situations covered such items as incentive wages, seniority clauses in union contracts, standards for inspectors, and who decides to shut down the operation.

Management Night May 4, will be held at Castigilia's Restaurant, Harrisburg, Pa. Rocco Fiaschetti, manager film quality control, Ansco Division, General Aniline & Film Corp., Binghamton, N.Y., will present a non-statistical talk. The values of better administration of this function will be discussed. He is a well qualified speaker with a broad experience in administrative fields.

HARTFORD . . . Eric J. Schneider, vice president, Engis Equipment Co., spoke on "Flatness, Straightness, Roundness and Surface Finish," at the monthly meeting Feb. 16.

William H. Gourlie, R. Hartman, B. Manes, J. Frost, and J. Connell, all experts in the field of air gaging, addressed the Hartford section at a special meeting Feb. 29 at the Royal McBee Corp. With the aid of slides and movies, the panel discussed "Air Gaging — What It Is and What It Does." A display of Sheffield's newest air gaging equipment was on hand for everyone to observe.

Also invited as guests of the section were 70 graduating students of the four courses offered by the Hartford section this year. The four courses were basic statistical control, intermediate statistical control, design of experiments, and principles of measurements and gaging. Diplomas were presented to the graduates.

For the closing meeting of the year, we are very fortunate to have as our guest speaker Dorian Shainin, Rath and Strong, Inc., No one should miss this meeting, so invite a friend and bring him or her along to hear one of the most interesting speakers in this country. See you all there.

HUNTSVILLE . . . At the January meeting, Roger W. Anderson delivered an extremely interesting lecture on "Applications of Analysis of Variance and Experimental Designs." Mr. Anderson is supervisor of quality control of Texas Instrument, Inc., Dallas, Texas.

The Huntsville section participated in the activities in Huntsville for the advancement of engineering through Engineering Week.

The speaker for the regular February meeting was Robert M. Laforge, Department of Industrial Engineering, University of Tennessee.

INDIANAPOLIS . . . Gayle McElrath, head, industrial engineering Department, University of Minnesota, spoke on "Some Economic Considerations of Inefficient Statistics," at the meeting Feb. 24.

Mr. McElrath's talk was both humorous and informative as usual. A large audience was pleased with his down-to-earth presentation of many of the highly statistical approaches to industrial problems. Cafeteria dinner and lecture were held at Atherton Center, Butler University.

IOWA . . . On Feb. 26, the University of Iowa section presented to its members Harmon S. Bayer, consultant, Detroit, Mich. His topic was "How to Use X Bar and R Charts Effectively." He stressed the need not to plot the result on the chart, but to plot the cause on the chart. This meeting was truly one of the highlights of our Calendar of Events for 1959-60.

On April 29, Leon Bass will speak on "Short Run Quality Control," at the John Deere Little Theater, Moline, Ill. This subject should be of interest to many people as most industries have short run jobs of some type. This should be another excellent meeting.

JOPLIN . . . The meeting scheduled for Feb. 15 was cancelled due to inclement weather.

Recently pictured during a Lexington section meeting were, from the left, Roy S. Harney, acting chief, inspection office, Lexington Signal Depot; Colonel Kenneth M. Gonseth, Commander, Lexington Signal Depot, and John F. McAreavy, an instructor and consultant at Ordnance Management Engineering Training Academy.

LEXINGTON . . . Our regular monthly meeting ran into some bad weather trouble and as a result only a few were in attendance. John F. McAreavy, currently an instructor and consultant at Ordnance Management Engineering Training Academy, spoke on "Statistical QC Training in Ordnance Corps." The meeting was held at the Lexington Signal Depot.

Earlier in the day Mr. McAreavy spoke at the Lexington Signal Depot to a top management group. This group included representatives from IBM, Texas Instrument Co., General Electric, Parker Seal Co., U.S. Post Office, Bluegrass Ordnance and Lexington Signal Depot. His topic at this session was "Basic Statistical QC Concepts and Their Role in Decision Making."

On May 12, the Lexington ASQC and ASTE organizations will hold the annual combined meeting. This year the ASTE will be host.

LIMA . . . Ladies' Night featured orchids for the guests, a welcome from William E. Barker, district representative, and our guest speaker, Miss Frances Huntington, who spoke on "What Quality Control Means to the Housewife." Following the meeting, the ladies toured the inspection facilities of the fully automated engine plant of the Ford Motor Co., in Lima, Ohio.

At the request of local industries and individuals as well, the Lima section is repeating its course in basic statistical QC.

LOS ANGELES . . . During February, Ray Primmer of QRA, Inc., organized the first meeting of the Inspection Division of the Los Angeles section. The need for a down-to-earth treatment of inspection problems has been apparent in this area for a long time. The meetings are non-dinner, and various manufacturers of inspection equipment are invited to introduce their products and explain how to use them for their basic purpose as well as discuss little known uses which would enhance their value in inspection. The enthusiasm for such a division can be shown by the 150 persons which attended the first meeting. More than 300 are expected to be the average number in attendance at future meetings. The idea here should spread rapidly. The need is present and the inspector is waiting.

More than 300 persons attended our one-day Reliability Symposium held at the Statler-Hilton (in Los Angeles, not New York as previously reported) and heard Harry Powell, STL; John Riordan, DOD; and Maj. Gen. Ben I. Funk, SBAMA; Les Ball, consultant, and Herschel Eppenstein, Convair-Astranautics, discuss the organization and management of reliability programs. Jack Lancaster, USAF-BMC and Frank Squires, consultant, handled the affair.

Harry Romig, Hoffman Laboratories, assisted in guiding more than 125 persons at a joint ASQC-IRE-PGRQC plant tour of the AGREE testing facilities at Hoffman during February.

LOUISVILLE . . . Twenty-eight members and guests met at Jimmy Lynn's Restaurant Feb. 8 for a 7 p.m. dinner, which was preceded by a social half-hour.

The date of the Annual Banquet of the Louisville Engineering and Scientific Societies Council was announced at the business meeting. It has been set for May 26. The Nominating Committee for the 1960-61 slate was appointed.

The evening's guest speaker was Carl Noble, director of customer relations, Kimberly Clark Corp., Neenah, Wis. His topic was "Statistics in Operations Research."

Dr. Noble made so many good points and is such an interesting speaker that we will sum up his talk by saying "Don't ever miss an opportunity to hear him speak." We think his reputation of being one of the country's most sought after speakers is well deserved. And Dr. Noble's ideas are practical!

MEMPHIS . . . A timely event occured during February when the section was privileged to hear a talk by J. M. Farmer of the Internal Revenue Service. Mr. Farmer spoke on "Statistical Applications in the Department of Internal Revenue." This meeting was the section's first attempt at a "Ladies' Night." The evening featured a dinner before the meeting, followed by a plant tour of the Continental Bakery.

METROPOLITAN . . . The Metropolitan Conference on Quality Control was held Feb. 26-27, at the Hotel Statler-Hilton, N.Y.

On May 10, at 8 p.m., our monthly meeting will be held in Newark. G. Sheel and S. Sherwood will act as panel moderators in discussing the topic, "Inspection Problems." At 7 p.m. we will hold one of our pre-meeting clinics. Come out for a valuable evening.

MID-HUDSON . . . Albert M. Dexter, director of Metrology, Pratt & Whitney Co., spoke on "Zero Point One," at the meeting Feb. 2 at the Poughkeepsie Inn.

Mr. Dexter reported on progress toward splitting an inch into ten million parts. A brief background was given on how the program was started by the National Bureau of Standards, and the way in which the speaker has been associated with it.

A short history of standardization was presented, with a discussion of the present international value of the inch. Instruments, materials and techniques used, along with some of the problems and results found to date, were described.

Mr. Dexter concluded with a word as to what remains to be done in the future to make use of what has already been accomplished.

MILWAUKEE . . . For the second month in a row, section members and guests were treated to a very interesting and witty presentation by a member of the Mathematics Research Center of the University of Wisconsin. This month's speaker was J. Stuart Hunter, whose topic was "Some Experimental Designs and Process Development." Mr. Hunter's presentation was a logical sequence to G. E. P. Box's talk in January.

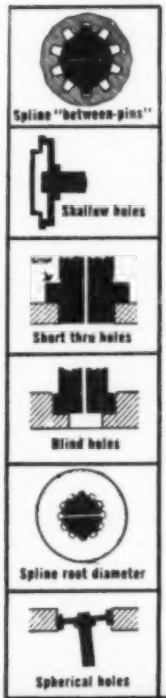
Seventy-one persons heard Mr. Hunter's talk, with more than 60 of them attending the buffet supper, which preceded the talk.

The afternoon training sessions were handled by section members Ray Wachniak and Jim Schaefer.

The May meeting, which is traditionally the annual business meeting of the Milwaukee section, will be held at the Miller Inn of the Miller Brewing Co.

MINNESOTA . . . On Feb. 18, 180 men and women representing 42 companies in Minnesota, Wisconsin and Illinois, attended the Ninth Annual Industrial Clinic for Quality Control, at the Curtis Hotel, Minneapolis. Sessions were presented on reliability, quality control procedures and inspection. The luncheon speaker was Gayle W. McElrath.

The following ASQC members presented papers: Benjamin Epstein, Stanford University; Stephen Adams,



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MONTREAL . . . On Feb. 17, J. F. Verigan of the Ormet Corp., Hannibal, Ohio, spoke on "Interesting Plant Personnel in QC." Mr. Verigan gave an insight into the behavior and motivation of people and related problems in the application of industrial quality control. Selling a QC program to both operators and management was explored during the question period. E. N. Beckett of Northern Electric, Montreal, was the moderator.

F. A. Gnaedinger, production control superintendent, Canadian Celanese Limited, Drummondville, Quebec, will speak on a subject with the intriguing title of "Pencil, Paper, and Prophets," at the May meeting. This will be held at the Canadian Industries Limited Building at 8:15 p.m., May 18.

MUNCIE . . . A most enjoyable time was had by all attending "Ladies' Night" at the Top Hat Feb. 18. Corsages were presented to the ladies. Guest speaker was Phil Eskew, superintendent of schools, who presented an entertaining talk.

NORTHEAST TENNESSEE . . . The eleventh meeting of the Northeast Tennessee section was "Management Night." The section met at the S. E. Massengill Company Cafeteria in Bristol Feb. 9. Guest speaker was A. F. Johnson, assistant director of operations, Buckeye Cellulose Corp., Memphis, Tenn. The meeting was preceded by panel discussions on "Sequential Sampling," and "Statistical Methods for Development and Process Improvement." A steak dinner was served to 93 members and guests. Movies of the meeting were televised by WCYB-TV, on the station's eleven o'clock news program.

NORTHEASTERN INDIANA . . . On Feb. 18, members were privileged to hear from Cherles H. Cowles, Industrial Engineer, Toledo Stamping and Manufacturing Co., Toledo, Ohio. Since graduating from Purdue University, Mr. Cowles has had considerable experience in the quality control field. He is a member of the ASQC, American Society of Tool Engineers, and the American Institute of Industrial Engineers.

Mr. Cowles spoke on "A Successful QC Program for a Job Sampling Plant." The talk covered general QC applications and had pertinent information for everyone. After the talk, members had many questions. The fact that Mr. Cowles had to catch a plane prevented the meeting from lasting into the late hours.

OMAHA-LINCOLN . . . The February meeting of the Omaha-Lincoln section was a joint meeting with the Cushman Foreman's Club, at the Cushman Motor Co., Lincoln, Nebr. Three members of the section, Niles Bernard of the University of Nebraska; R. W. Borgstad of Western Electric, and W. S. Jolitz, Goodyear Tire and Rubber Co., presented the program. This was a discussion of the principles of QC and the application of a QC program.

PARKERSBURG . . . The executive committee met at the Howard Johnson Restaurant, on Feb. 1.

A business machine exhibit was conducted during the February meeting, which was held in the ballroom of the Chancellor Hotel, Feb. 26, from 12 noon to 9 p.m. Local office suppliers were represented. Exhibitors included Olivetti, Friden, Victor, Monroe, and National Cash Register. This exhibit made a hit both with local industry and the general public.

PENSACOLA-MOBILE . . . The Beta Ray Profiler in QC, presentation, which was scheduled for the regular meeting, was postponed due to illness in the speaker's family. Substituted were color movies of USAF Supersonic Sabres in acrobatic flight, and Air Force News Clips of 1958.

The program scheduled for May will be "New Developments in the World of Communication," presented by the Southern Bell Telephone and Telegraph Co.

William J. Hepburn, Lukens Steel Co., spoke on "Quality Specifications," at the technical session of the February meeting of the Philadelphia section. Mr. Hepburn is a member of the Philadelphia section.

PHILADELPHIA . . . Simon Collier, ASQC Fellow, Metropolitan section, was the guest speaker at the Philadelphia section meeting. His interesting presentation pointed out the human element factor in getting QC systems to work. The technique used to accomplish this was to take movies of operations showing men and machines. These movies were later shown to supervisors and workmen to indicate where improvements could be made. Mr. Collier, who is presently retired from the Johns Manville Corp., but still active in QC, showed a color movie of production and QC produced by Johns Manville.

Technical Session A featured W. J. Hepburn, Lukens Steel Co. He had been scheduled for March, but made a switch with Max Traux by mutual agreement. Bill Hepburn emphasized the team approach required to put out a good and economical specification. With posters and handouts of actual specs he demonstrated the various methods used at Lukens Steel to put out a purchase specification with the least burden on the purchasing department as well as the supplier.

Albert L. Goldsmith of RCA capably handled Session B. He demonstrated by reliability computations on the board, the chances of meeting the required objectives of reliability as applied to tests in the electronics field. A. Goldsmith and W. Hepburn are both active members of the Philadelphia section.

Jules Mehalek, nominating chairman, presented a slate for the 1960-61 election of officers who had agreed to be nominated. The chairman also called for nominations from the floor for each office.

PHOENIX . . . The January meeting, first ladies night of the year, was held at Neptune's Table. Walter O. Lowrie, manager of quality engineering, The Martin Co., Denver, Colo., gave a very excellent talk. Mr. Lowrie's subject was quality engineering's role in the reliability of the Titan ICBM.

On May 19, Kermit Skeie, manager of the Western Division, Magnaflux Corp., will address the section. His topic will be cost reduction through non destructive testing. This will be a dinner meeting and will be held at Yancey's, 8500 N. Central Ave., 6:30 p.m.

PITTSFIELD . . . On Feb. 10, a talk was given by A. P. Stergion, QC manager, Corning Glass Works, on "Vendor Consumer Relations," to approximately 50 members. He listed five or six major areas that effect vendor consumer relations. There were meetings with the customer and vendor for discussion of long range problems; review of specifications and limits; establishing what is important and classifying of defects; methods of inspection and gaging and quality level concept.

clinics, conferences, and courses

MAY

. . . **2-13**--Short Course on Statistical Quality Control for the Textile Industry, the School of Textiles, North Carolina State College, Raleigh, N. C., contact D. B. Stansel, P. O. Box 5125, State College Station, Raleigh, N. C.

. . . 6—Quality Control in the Competitive Market All Day Seminar, sponsored by the ASQC Akron-Canton section, contact Walter C. Siff, the General Tire & Rubber Co., 1708 Englewood Ave., Akron 9, Ohio.

. . . 6-7 — Evolutionary Operations (EVOP) Course, sponsored by the ASQC Baltimore section, at the Lord Baltimore Hotel, contact E. M. Glocker, Research Dept., W. R. Grace & Co., Clarksville, Md.

. . . **9-13**—1960 Castings Congress and Exposition, Philadelphia, Pa., sponsored by the American Foundrymen's Society, contact Denham & Co., 925 Book Bldg., Detroit 26, Mich.; telephone WO 5-4941.

. . . **12-14**—Eleventh Annual Conference and Convention of the American Institute of Industrial Engineers, Dallas, Tex., contact P.O. Box 914, Irving, Tex.

. . . **16-18**—Symposium on Statistical Methods in the Pulp and Paper Industry sponsored by the Finnish Paper Engineers' Association in Helsinki, contact Nils J. Lindberg, general secretary of the symposium, the Finnish Paper Mills Association, Helsinki, Finland.

. . . 19-21—Course in the Evaluation and interpretation of physical and chemical testing methods, sponsored by the ASQC Chemical Division, Philadelphia, Pa., instructors will be Grant Wernimont, Eastman Kodak Co., and John Mandel, National Bureau of Standards, contact Richard A. Freund, ASQC Chemical Division Education Committee, Eastman Kodak Co., Film Testing Division, Kodak Park, Bldg. 6B, Rochester 4, N.Y.

. . . 24-26—14th Annual Convention and Exhibition of the American Society for Quality Control, Hotel Sheraton-Palace, San Francisco, Calif.

. . . 26-28—Third ASQC Workshop-Seminar, Management of Quality Control, Sir Francis Drake Hotel San Francisco, Calif., contact the Third ASQC Workshop-Seminar, ASQC, 161 W. Wisconsin Ave., Milwaukee 3, Wis.

. . . 30-31, June 1—Mid-Pacific Conference, Honolulu.

JUNE

. . . **5-9**—Summer Annual Meeting and Aviation Conference of the American Society of Mechanical Engineers, Statler Hilton Hotel, Dallas, Tex., contact L. S. Dennegar, American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y.

. . . **6-10**—Tenth Annual Program of Quality Control for the Graphic Industries, Rochester Institute of Technology, Rochester, N.Y., contact Harold M. Kentner, Extended Services Division, RIT, Rochester 8, N.Y.

. . . **7-17**—Second Annual Short Course on the Design of Experiments, Charles R. Hicks, instructor, and a concurrent Advanced Short Course in Quality Control, Irving W. Burr, instructor, at Purdue University, contact Mr. Hicks or Mr. Burr, Purdue University, Lafayette, Ind.

. . . **13-24**—Two University of Michigan Engineering Summer Conferences: Models and Simulation in Operations Research, and Foundations and Tools for Operations Research and the Management Sciences, contact R. E. Carroll, Engineering Summer Conferences, University of Michigan, College of Engineering, Ann Arbor, Mich., telephone NOrmandy 3-1511, Ext. 2079.

. . . **13-30**—Two sessions of the 17th annual Statistical QC Program for the Chemical Industries, Rochester Institute of Technology, Rochester, N.Y.; 1st session—June 13-20, 2nd session—June 23-30; Applications Seminar—June 21-22, contact Harold M. Kentner, Extended Services Division, RIT, Rochester 8, N. Y.

. . . **14-17**—Annual Cornell University Industrial Engineering Seminars, sponsored by the Department of Industrial and Engineering Administration, Sibley School of Mechanical Engineering, Cornell University, Ithaca, N. Y., participants enroll in industrial management, engineering administration, operations management of the smaller company, work measurement, systems simulation using digital computers, statistical decision-making: theory and applications, or statistical reliability analysis: theory and applications, and also attend general sessions, contact J. W. Gavett, seminar coordinator, Department of Industrial and Engineering Administration, Upson Hall, Cornell University, Ithaca, N.Y.

AUGUST

. . . **1-19**—1960 Statistical Methods in Industry Course, University of California, Los Angeles campus, five major courses are QC by statistical methods; industrial statistical methods; design and analysis of industrial experiments, industrial reliability, and basic measurements and standards. Participants will have a choice of seven seminar or special laboratory groups and a general lecture series. Instructors include I. W. Burr, Charles Hicks, L. A. Knowler and Robert C. McMaster, contact Edward P. Coleman, Department of Engineering, University of California, Los Angeles 24, Calif.

. . . **15-25**—Thirteenth Annual Intensive Course in Quality Control by Statistical Methods, a first course for executives and supervisory personnel, practical and mathematically nontechnical, instructors will be Fred Beeler, Western Michigan University; C. C. Craig, University of Michigan; E. G. Olds, Carnegie Institute of Technology, and Mason E. Wescott, Rutgers University; contact C. C. Craig, course director, 106 Rackham Bldg., Ann Arbor, Mich.

ASQC Annual Convention Future Dates

May 24-26, 1960	**San Francisco**
June 5-7, 1961	**Philadelphia**
May 23-25, 1962	**Cincinnati**
May 20-22, 1963	**Chicago**
May 4-6, 1964	**Buffalo**

Mid-Pacific Conference
May 30, 31, June 1, 1960 Honolulu

Baltimore EVOP Course May 6-7

An EVOP course, sponsored jointly by the ASQC Chemical Division and the ASQC Baltimore section, will be conducted May 6-7 at the Lord Baltimore Hotel, Baltimore, Md.

The course was announced by V. B. Shelburne, chairman, ASQC Chemical Division, and F. J. Cullen, chairman, Baltimore section. Instructors for the course will be J. Stuart Hunter, University of Wisconsin, Madison, Wis., and Truman L. Koehler, American Cyanamid Co.

This popular two day course is being featured for the first time in this section of the country and to date, the course is already 20 percent filled. Course fee is $85, which includes tuition, supplies, "EVOP" articles and two lunches. Contact Edwin M. Glocker, Research Dept., W. R. Grace & Co., Clarksville, Md. Mr. Glocker is registration chairman.

R. Powell, section chairman, was a guest at the Willie Leys lecture held in Pittsfield Feb. 24, in observance of National Engineers' Week. R. Hopley, membership chairman, represented ASQC on the Professional Societies Committee for observance of National Engineers' Week.

An executive committee was held Feb. 29, and plans were tentatively made for election of officers in April and the annual June outing.

Lloyd Knowler is shown as he discussed industrial problems, as based on his consulting work in quality control, at the January meeting of the Rockford section.

ROCKFORD . . . On Jan. 21, Barber-Coleman was host to the Rockford section. Lloyd Knowler, chairman of the department of mathematics and astronomy at the State University of Iowa, spoke on industrial problems as based on his consulting work in quality control. The meeting was attended by 60 members and guests.

SACRAMENTO . . . On Feb. 18, our dinner meeting was held at the Chuck Wagon. E. P. Coleman, professor of engineering at the University of California, was the guest speaker. Mr. Coleman, a graduate of Columbia University, has received national as well as regional recognition for his lectures concerning industrial management, quality control and industrial engineering. Sacramento section members and guests were honored with a presentation on "Dollars and Cents of Quality Control." Mr. Coleman's talk covered the problems of making decisions on the source of uncertainty, and the scientific methods used by QC personnel. Mr. Coleman closed his talk with the reading of the "Deacon's Masterpiece," by Wendell Holmes, "The One Horse Shay."

ST. CHARLES . . . More than 100 members and guests turned out to tour the General Electric appliance motor plant in DeKalb, Ill., Feb. 16. After the tour, the group "initiated" the new employee cafeteria with a delicious prime rib dinner. After dinner, GE quality control representatives presented various phases of their quality control program. Everyone considered the evening well worth the long drive home on extremely slippery roads. Our thanks go to the fellows at GE for a most enjoyable and informative evening.

Two training courses were begun in February — an intermediate 25 hour course in sampling fundamentals began Feb. 4, and a professional QC management seminar of 32 hours began Feb. 27.

ST. LOUIS . . . The Southern Illinois Sub-Section has been approved by the Society's Executive Committee for full section status, as of Feb. 18. The St. Louis section plans to present them with their charter at a joint meeting in June.

The section ranks third in the Saddoris Award points, as of the Dec. 24, 1959 report.

The Intermediate Class in QC started at the Pick-Melbourne Hotel on Feb. 18. Enrollment for this course was 35.

The 16th Midwest QC Conference will be held in St. Louis on Oct. 19, 20, 1961, at the Chase-Park Plaza Hotel. The Conference Planning Committee has been formed and is functioning.

H. O. Hehner, Monsanto Chemical Co., presented a talk at the Illinois Institute of Technology entitled "How You Can Make a Multi-Plant QC Program Work."

SAN DIEGO . . . Members are still talking about the fine Father-Son-Daughter meeting we had when the topic of "Space Travel," was given a thorough going over. The genuine enthusiasm shown by the youngsters was a pleasure to observe, especially during the question and answer period. What questions! It was a good thing that we had Mr. Ford, a real expert in the field, to provide answers. Our attendance of 250 plus at this meeting was one of the best. Dave Archibald, the sponsor of the meeting, is to be congratulated on an excellent program — we need more of the same!

SAN FRANCISCO . . . Our May Convention is rapidly approaching and the all-out effort by our section members is now showing results. The committees are tieing up the loose ends of their activities for the convention and feel that the many out-of-state visitors will be shown a pleasant and memorable time during their three day stay. C. E. Fisher, ASQC president, and Wm. Youngclaus, administrative secretary, flew out from the east to attend our Mar. 8 meeting. Mr. Fisher spoke on "Quality Control, A Look Forward," and discussed arrangements with the Convention Host Committee.

SOUTH TEXAS . . . The speaker at the March meeting, J. M. Wiesen, Sandia Corp., spoke on "Reliability vs. Quality Control." Mr. Wiesen was an ASQC district representative in 1952.

A pre-meeting training session on "Sampling for Administrative Purposes," was conducted by Spencer H. Gore of Price Waterhouse & Co.

A new three level educational and training program has been established and classes will start in the fall with a course in basic statistical QC. The following spring an intermediate or second level course will be offered. Work on the advanced level will be offered in conjunction with the University of Houston on a fall and spring semester basis.

SOUTHERN CONNECTICUT . . . Sixty members and wives attended the section's annual Ladies' Night meeting at the Half-Way House in Darier on Feb. 17. After dinner, Miss Bonnie B. Small, Western Electric Co., talked on "The Inside Story on Statistical QC." Directing her remarks to the wives in the audience, she did an excellent job of explaining in layman's terms just what QC is and how the people who work with it spend their day.

SYRACUSE . . . Two of our section members, John Duffy, Cowles Chemical Co., Skaneateles Falls, and K. L. Teegarden, Bristol Laboratories, Syracuse, served on the committee of judges for the student exhibits and demonstrations at the Science Fair held at West Genesee Central School.

The section, as a member of the Technical Societies Council, helped defray the expenses for student dinners at the Engineering Symposium.

A series of weekly panel discussions on QC has been held by the Auburn Industrial Management Club as a preliminary to a possible basic course. Joseph D. Portello, one of our members, headed the panels which answered practical problem questions of local QC personnel. Guest speakers included George A. Endrich, Frank P. Grimes, and Robert Hofstead, also of our section.

A basic course in QC is being conducted in Fulton, N.Y., in conjunction with the Adult Training Program. The course is sponsored by Armstrong Cork Co., Nestle Chocolate Co., and Sealright Corp., for anyone interested in the field.

TENNESSEE . . . Two interesting talks were enjoyed by members and guests at the section meeting Feb. 11. Donald A. Gardiner, Oak Ridge National Laboratory, spoke on "Linear Regression—Why It Is the Best Calibration Method," illustrating the basic assumptions underlying the linear regression method and the reasons that a linear regression curve is most efficient.

David Chambers told of the goals of ASQC and discussed the membership history of the Society.

Three talks on the various phases of quality control will be given at the May 12 meeting.

TORONTO . . . Frank Caplan, Jr., the speaker scheduled for our meeting Feb. 3, was unfortunately unable to attend, and his paper was presented by one of his associates, Frank Winnie, also of Westinghouse Electric Corp., Blairsville, Pa. The subject was "Vendor Relations," and Mr. Winnie gave a unique twist to the proceedings by pointing out that his company at that time was the Vendor under discussion in Mr. Caplan's paper. The lecture was followed by a lively debate in which it seemed that just about all of the 35 members present had their say.

Thirty-three members attended the last Study Group for this season on Feb. 16, which was presided over by Bob Cardno. The theme was "Day to Day Inspection Problems," and as might be expected with such an open subject there were many varied and interesting case histories aired and debated. It is generally felt by everyone who attends these study groups that they are an extremely useful and worthwhile proposition and a valuable means of presenting the other fellow's approach to our day-to-day problems.

TUCSON . . . The section is looking forward to the visit of Frank Caplan, Jr., QC manager, Westinghouse Electric Corp., Blairsville, Pa., at the May meeting. "Electronics Production Line Experimentation," will be the subject of his talk. At this meeting there will also be a clinic on transistors, conducted by Ed Orinski, Hughes Aircraft Co.

MONTREAL . . . The Ottawa Sub-Section reports that on February 17, the guest speaker who had been scheduled to discuss packaging was not able to be present. Through the cooperation of the DND film library, we were fortunate to be able to show two films on packaging, and two films covering statistical process control.

The showing of these films proved to be very timely as we had representatives from the Department of Agriculture who are interested in both aspects as it applied to food produce and manufacturers who are supplying electronic navigation systems to world markets. Once again, it was proven to our membership that everyone's problems are almost the same even if on the surface eggs and apples appear to present different problems to electronic flight systems and stoves.

UTICA . . . On Feb. 25, the joint Engineering Societies Meeting was held at the Beeches in Rome, N.Y. The main speaker, Capt. Kenneth M. Tebo, USN, spoke on "What is Polaris?" By means of color slides he explained some of the problems the Navy was faced with during the past two years of building the Polaris fleet. Some two hundred listened to Capt. Tebo.

WASHINGTON, D.C. . . . Fifty section members and guests were present at the February meeting to hear John Neter of the University of Minnesota speak on "Sampling Techniques in Accounting and Auditing." Among the points Mr. Neter emphasized were the preference for a positive-type questionnaire rather than a negative one; the importance of a common lingo between accountant and statistician, and a distinction between response bias and response variance.

The meeting as usual was preceded by cocktails and dinner at Rich's Restaurant. However, because of the continued larger-than-before-attendance, it is necessary to move to larger quarters in the General Services Administration Bldg., across the street from Rich's, for the after-dinner announcements, lecture, and discussion, which usually lasts from 8 to 9 p.m., or shortly thereafter.

WESTERN MASSACHUSETTS . . . F. C. Hartwell spoke to 34 at our meeting Feb. 9, on the aspects of "Art Can Become a Science," with, of course, specific reference to the science of quality control. As he is associated with the Schweitzer Division, Kimberly Clark Corp., a paper industry business, Mr. Hartwell has a rich source to draw from in developing the theme of art or science.

On May 10, Richard M. Story, Connecticut University, will talk on the role that our educational centers play in spreading the quality control gospel. He has directed for many years the "Horse's Mouth Course," and the "Advanced Statistical QC Institute," which is given annually at the University of Connecticut.

WINNEBAGO . . . At the afternoon session, a tour through the mill of Bergstrom Paper Co., Neenah, Wis., Carl E. Noble, Kimberly Clark Corp., Neenah, and Ed Thode, Institute of Paper Chemistry, Appleton, Wis., discussed "Operations Research and Systems Engineering in the Paper Industry." Mr. Noble covered applications in business and management areas and Mr. Thode the technical applications.

At the evening dinners and speech, J. Stuart Hunter, University of Wisconsin, discussed Evolutionary Operations Techniques.

WORCESTER . . . On Feb. 18, a joint meeting was held with the American Institute of Industrial Engineers at the Worcester Polytechnic Institute. A large turn-out was on hand for a very interesting discussion on quality control and industrial engineering. Arnold O. Putnam, Rath & Strong Co., was the speaker. Mr. Putnam covered the use of statistical and quality control techniques in the field of time standards. This included plotting and analysis of the precision of element standards, work sampling, and the use of histograms for auditing incentative plans to keep them up-to-date. All of the techniques were well-known in the QC field, but Mr. Putnam showed how they could be used to advantage in other fields such as industrial engineering.

On May 19, the section will hold the last meeting of the current year. This will be management night, and we are very fortunate to have Robert C. Sprague, founder and chairman of the Board of the Sprague Electric Co., as speaker. Mr. Sprague's topic for that evening will be "Certain Aspects of Our National Security."

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Table of Contents, Vol. 2, No. 5, February 1960

Statistical Estimation of the Gasoline Octane Number Requirement of New Model Automobiles, C. S. BRINEGAR, R. R. MILLER

The Effect of Sequential Batching for Acceptance-Rejection Sampling Upon Sample Assurance of Total Product Quality, M. HALPERIN, G. L. BURROWS

Elements of the Theory of Extreme Values, R. E. BARLOW, L. C. HUNTER

Aids in Fitting the Gamma Function by Maximum Likelihood, J. A. GREENWOOD, D. DURAND

Experimental Designs to Adjust for Time Trends, HUBERT M. HILL

Tests for the Validity of the Assumption that the Underlying Distribution of Life is Exponential—Part I, B. EPSTEIN

Programming Fisher's Exact Method of Comparing Two Percentages, W. H. ROBERTSON

Some Remarks on Wild Observations, W. H. KRUSKAL

Misclassified Data from a Binomial Population, A. C. COHEN

Notices

Book Reviews

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WHY NOT SEND YOURS IN TODAY?

YOUNGSTOWN . . . John W. W. Sullivan, American Steel and Iron Institute, spoke on "Statistical Methods in Steel Technology," at the January dinner meeting, which was attended by a large representation from the steel industries of the Shenango and Mahoning Valley. Mr. Sullivan remarked that he was enjoying this meeting because of the number of people present who were "old friends," and that it was like "old home week."

Section chairman Paul Belter stressed the importance of building the membership for the section. He pointed out that although the membership has been growing steadily, it has not kept pace with interest shown by attendance.

C. V. Crockett of the GMC Truck and Coach Division, "educated," the Youngstown section at the February meeting on the importance of reliability in engineering. It was a very successful evening, with some 125 members and guests in attendance. The GMC engineer stressed the importance of simplicity by comparing the electrical wiring of an old model automobile with that of today. Although his subject was of a serious nature, Mr. Crockett introduced much humor into his talk.

Mr. Belter announced the appointment of Larry Pogue of Packard Electric to chairman of the professionalism committee and Robert Jones of Copperweld Steel to head the nominating committee for the spring election of officers.

Significant Differences

. . . Allentown-Bethleham—**John M. Nemecek** of the Allentown Plant Western Electric Co., has been promoted from section chief, alloy junction transistors, to department chief, mercury relays and switches.

Miss Bonnie Small was missed at our Feb. 10 meeting; however, she was spreading the QC gospel at a meeting of the Business and Professional Women's Club of Allentown on the same evening and even Bonnie has yet to find a means of being in two places simultaneously!

Lee B. Steele, U.S. Army Signal Corps., has been temporarily transferred from the Allentown-Bethlehem area to Philadelphia.

Ken Stephens, our genial chairman, is looking forward to seeing spring since moving into his new home in the country!

. . . Binghamton—The section welcomes to ASQC **Dick Moebus,** who was recently promoted to project engineer in charge of quality engineering at Endicott.

Ivy Runyon has been promoted to field photographic engineer for Ansco.

Stan Rogge is now head of QC statistical analysis for Ansco.

. . . Boston—**Daniel E. Phipps** to quality manager and **Robert A. Fabian** to quality assurance engineer at Keystone Mfg. Co., Dorchester, Mass., are promotions well deserved.

And another move upward, and over, to the Ludlow Mfg. & Sales Co., Needham, Mass., for **Oliver P. Beckwith,** as QC director.

B. P. Goldsmith should have been reported as taking a position as *associate* professor at Northwestern University—not an *assistant!* Sorry I goofed.

Reporter to **IQC** and Newsletter editor will be **Howard L. Keefe,** B. F. Goodrich Co., Watertown, Mass.

Also, for 1960-61, yours truly, **Ted Brownrigg,** will head the Saddoris Award Contest Committee.

. . . Charlestown—**Wally Kellogg,** section treasurer, has been promoted to assistant engineering superintendent of the technical service department, Monsanto Chemical, Nitro, W. Va.

. . . Cincinnati—**R. N. Johnson** represented the Kroger Co., in a discussion with the secretary, department of health, education and welfare, and the Food and Drug Administration regarding dyes and foodstuffs.

The Cincinnati section's professionalism in QC committee is comprised of the following Cincinnati members: **Robert Fopma,** department of mathematics, University of Cincinnati; **Louis Zimov,** vice president of operations, Crosley Division of AVCO, and **H. W. Hudepohl,** QC manager, General Electric Co., Cincinnati.

. . . Cleveland—The first jointly sponsored educational program with Western Reserve University and the Cleveland section has just been completed. The spring program consisted of two courses which were taught by Messrs. **J. N. Berrettoni, F. C. Leone** and **H. Wadsworth.** The courses were "Fundamentals of Quality Control," and "Sampling Techniques."

. . . Dallas-Fort Worth—Thirteen members of the Dallas-Fort Worth section attended the first QC symposium of the San Antonio Section on Feb. 20. Included in this group was **R. W. Anderson,** and **Glenn E. Owen,** who spoke at the symposium. The San Antonio section symposium committee is to be commended for a well organized and conducted conference.

. . . Hamilton—**Stan Manchuck,** program committee chairman, formerly tool co-ordinator of the motor and generator division, Canadian Westinghouse Co., Hamilton, has been appointed QC supervisor of that division. Also, Mr. Manchuck was recently married.

Neil McCarthy, section vice chairman, has been promoted from superintendent of QC, electronics division, Canadian Westinghouse Co., Ltd. to QC Consultant of the switch gear & control division.

. . . Hamilton-Middletown—**W. G. Thompson,** supervisor, statistical services, Champion Paper & Fibre Co., Hamilton, Ohio, has been temporarily assigned as special assistant to the production manager.

DuWayne R. Carlson, staff assistant to the process controls manager, Champion Paper & Fibre Co., Hamilton, Ohio, has been temporarily assigned as supervisor, statistical services, with Champion.

Brooks Breidenthal, technical service engineer, controls development unit, has been assigned to the training section, Champion Paper & Fibre Co., Hamilton, Ohio.

Robert L. Harris, computer programmer, Ohio division has been transferred to the general office data processing unit, Champion Paper & Fibre Co., as chief programmer.

. . . Harrisburg—**James R. Ramsey,** Harrisburg section has accepted a position as quality manager with Audio Mfg., Stamford, Conn. At present Mr. Ramsey is quality manager, Schick Inc., Lancaster, and has been section chairman for the 1959-60 term. Good luck, to you, Jim.

Ladies' night was enjoyed by all with a plant tour of Lambert-Hudnut, Lititz, Pa. Dinner-dance followed at the Overlook Country Club. **A. F. Flohr,** QC manager, Lambert-Hudnut, welcomed the ladies and explained the plant facilities. (This event had been reported in January as scheduled to be held at the General Sutter Hotel, Lititz, Pa., with **Paul A. Rohlf,** section member, as the speaker. These plans had to be changed after they had been submitted for publication.).

. . . Hartford—**Frank Hauman, Jr.,** past chairman, has taken over a new post at Underwood Corp. Frank was formerly QC supervisor at Royal McBee Corp.

. . . Lexington—**Richard J. Gibson,** Corning Glass Co., has been transferred to the Corning, N.Y., plant.

Don W. Freeman, U.S. Army, has returned after a two month trip to Germany and France.

. . . Lima—**Douglas Stewart,** assistant QC superintendent, Lima, Ohio, X-L-O, has been promoted to Chief Inspector at the X-L-O Plant in Elwood, Ind. Chief production at the new plant is jet engine compressor blades and vanes.

Richard Bucher, general foreman of inspection and Lima X-L-O, is now assistant QC supervisor.

Award for Best Paper Presented at a Textile Division Conference was presented to Oliver Beckwith, Ludlow Manufacturing Co., (left), by Robert G. Mitchell, International Latex, chairman of the ASQC Textile Division.

Award for Distinguished Service to the Textile Division is presented to John H. Reynolds, Celanese Corp., (left), by D. S. Hamby, North Carolina State College.

Awards Presented at the Tenth Textile Division Conference

The Textile Division honored two of its members with awards at its recent Tenth Annual Conference, which was held on Feb. 18-19, at Clemson House, Clemson, S.C.

Awards were presented to Oliver P. Beckwith, QC director, Ludlow Manufacturing Co., Needham, Mass., and John H. Reynolds, Celanese Corp., Rome, Ga.

For the Best Paper Presented at a Textile Division Conference, Mr. Beckwith received an inscribed desk set and a cash award of 50 dollars. His paper, "Management of Quality Control in Cotton Manufacturing," was published in Textile Division Papers of 1954.

Mr. Reynolds received an inscribed desk set for Distinguished Service to the Textile Division.

The presentations which took place during the annual banquet, were made by Robert G. Mitchell, International Latex Corporation, and Dame S. Hamby, North Carolina State College.

Another highlight of the Division's annual banquet was its speaker, Cleveland Adams, School of Textile Technology, Auburn University. Covering a recent 35,000 mile trip around the world for the purpose of studying and appraising the textile industry in 14 foreign countries, Mr. Adams' report, with very interesting sidelights, was enthusiastically received by the largest group ever to attend a Textile Division Annual Banquet.

Cleveland Adams, Head, School of Textile Technology, Auburn University, addresses the annual banquet of the Textile Division. Seated, from the left, are E. A. LaRoche, Clemson College, and L. Mueller, Dixiana Mills.

Conference chairman Robert Heiland, Kurt Salmon Associates, reported that 272 people attended, a figure far above any previous years. Recognition was given by Mr. Heiland to committee members J. B. Curley, American Viscose, program; E. A. LaRoche, Clemson College, arrangements; C. D. Ferris, Mohasco Industries, secretary-treasurer; W. B. Maynard, Philadelphia Textile Institute, publications; E. H. Stier, moderators & monitors; and L. Mueller, Dixiana Mills, publicity.

SECTION CALENDAR (APRIL 25 TO MAY 31)

SECTION	DATE	PLACE	TIME	SUBJECT	SPEAKER
Albuquerque	May 9	To be announced	7:00 p.m.	Annual Banquet	To be announced
Albany	May 12	Hot Shoppe, N. Blvd & Shaker Rd.	6:30	Symposium on Evolutionary Operations	Irwin Shupe (Moderator), Winthrop Laboratories, Rensselaer, N. Y.
Allentown-Bethlehem	May 11	Hotel Traylor, Allentown, Pa.	6:30	Local participation	Section members
Baltimore	Apr. 19	Engineers' Club	6.00	To be announced	J. Stuart Hunter, University of Wisconsin, Madison, Wis.
Battle Creek-Kalamazoo	May 19	Jack Howard's Escape, Battle Creek	6:30	QC With Staggering Results (Ladies' Night)	Howard La Violette, State of Michigan Alcoholic Beverage Tester.
Binghamton	Apr. 30	Cornell University, Ithaca, N. Y.	9:00 a.m.	One Day QC Clinic	12 sessions, 12 speakers
	May 10	Sheraton Inn	7:00 p.m.	Survey of Engineering Computers and Application	John Kennerly, KCS Ltd., Toronto
Boston	May 12	MIT Faculty Club	6:30	Management Supported QC Programs	Leon Bass, General Electric Co., Cincinnati, Ohio
Buffalo	Apr. 25	Town of Tonawanda, N. Y.	6:30	Can QC Pay Its Own Way? (election of officers)	Robert Schin, Western Electric Co., Allentown, Pa.
	May 16	Chevrolet Motor Div., GMC, Tonawanda, N. Y.	7:30	Plant tour	Herbert Hougland, Chevrolet, GMC, Tonawanda, N. Y.
Charleston	May 19	To be announced	7:30	The Art of Cutting Gem Stones (Ladies' Night)	T. W. Heiskell, Union Carbide Chem. Corp., S. Charleston, W. Va.
Cincinnati	May 18	Engineering Society Bldg.	8:00	Practical QC at the National Cash Register Co.	William E. Smith, National Cash Register Co., Dayton, Ohio
Cleveland	May 6	Cleveland Engineering & Scientific Center	7:45	Mobilizing SQC for the National Economy	William Pabst, BUORD, Navy Dept., Washington, D. C.
Columbus	May 18	Western Electric Co., Columbus, Ohio	7:30	Plant tour	.....
Dallas-Fort Worth	Apr. 28	Arlington State College, Arlington, Tex.	8:00	Process Control in a Job Shop	Frank Caplan, Jr., Westinghouse Electric Corp., Blairsville, Pa.
	May 26	Arlington State College, Arlington, Tex.	8:00	Overlapping Tolerances	J. A. Mazzola, IBM Corp., Endicott, N. Y.
Evansville-Owensboro	May 14	Westhaven Gun Club, Evansville, Ind.	7:00	QC—Woman's Oldest Weapon (Ladies' Night)	Gayle McElrath, University of Minnesota, Minneapolis, Minn.
Hamilton	May 12	Canadian Westinghouse Co. Ltd.	8:00	Reliability	L. Marzee, Canadian Westinghouse Co. Ltd.
Harrisburg	May 4	Castigilia's, 706 N. 3rd St., Harrisburg	6:30	QC for Management (Management Night)	Rocco Fiaschetti, Ansco Div., General Aniline & Film Corp., Binghamton, N. Y.
Hartford	May 16	Nutmegger House, Newington, Conn.	6:30	An A to Z Application of a Statistically Designed Experiment	Dorian Shainin, Rath & Strong, Inc., Boston, Mass.
Indianapolis	Apr. 19	International Harvester Engine Plant	5:00	Plant tour and program	To be announced
University of Iowa	Apr. 29	Moline, Ill.	8:00	Short run QC	Leon Bass, General Electric Co., Cincinnati, Ohio
Joplin	May 19	Joplin	7:00	In-Plant QC Training	Joseph Movshin, Ramsey Corp., St. Louis, Mo.
Lexington	May 12	.....	....	(Joint meeting, ASTE as host)	To be announced
Louisville	May 9	Jimmy Lynn's Restaurant	6:30	Use of Computers and Allied Equipment in QC	J. O. Renfrew, IBM, Youngstown, Ohio
Metropolitan	May 10	Newark, N. J.	7:00	Inspection problems	George R. Scheel, Sonotone Corp., White Plains, N. Y.
Mid Hudson	May 3	The Flamingo, Saugerties, N. Y.	7:00	Maldistribution, Key to the QC Effort	C. W. Carter, QC Consultant, Longmeadow, Mass.
Milwaukee	May 9	Miller Inn, Miller Brewing Co., Milwaukee, Wis.	7:00	(Annual Business Meeting)	.....
Minnesota	Apr. 26	Mutual Service Insurance Co.	6:00	Presentation of Data	H. J. Gulde, Minneapolis Honeywell, Minneapolis, Minn.
	May 19	Ballantine VFW Post, 2916 Lyndale St., Minneapolis	6:00	(Business and Dinner Meeting)	.....
Montreal	May 18	Canadian Industries Limited Bldg., Montreal	8:15	Pencil, Paper, and Prophets	F. A. Gnaedinger, Canadian Celanese Ltd., Drummondville, Quebec
(Ottawa Sub-Section)	May 18	NRC	8:00	Inspection by Variables	Representative from the DND
Muncie	May 19	Ball State Teachers College Student Center	6:30	Examples of Experimental Design Applied to Marketing Problems	Charles Collard
Omaha-Lincoln	May 13	Dale Products Co., Columbus, Nebr.	7:00	Plant tour	To be announced
Parkersburg	May 11	Chancellor Hotel	7:30	(Ladies' Night)	A. C. Rosander, Internal Revenue Service, Washington, D. C.
Pensacola-Mobile	May 24	Officers' Club, Brookley AFB, Mobile, Ala.	6:30 p.m.	New Developments in the World of Communication	Representative, Southern Bell Telephone and Telegraph Co.
Philadelphia	May 18	Germantown Cricket Club	6:15	Quality in the Automotive Industry	E. G. Budd, Jr., The Budd Co.
Pittsfield	May 11	Stanley Club	6:45	Movie—Modern Quality Control	Simon Collier, QC Consultant, New Rochelle, N.Y.
St. Charles	May 17	Tally-Ho Inn, West Chicago, Ill.	6:30	Automotive QC	Mr. Bowers, Chrysler Corp.
St. Louis	May 20	Shell Oil Co., Wood River, Ill.	6:30	Plant tour	Ivan S. Cliff
(Illinois Sub-Section)	.....	.....	....	Plant introduction	V. L. Wimmer, Olin-Mathieson Chemical Co.
South Texas	May 25	Houston Engineering & Scientific Society, 2615 Fannin St., Houston	7:00	Overlapping Tolerances	J. A. Mazzola, IBM Corp., Endicott, N.Y.
Southern Connecticut	May 18	Bridgeport, Conn.	6:30	To be announced	J. M. Juran, Management Consultant, New York
Syracuse	Apr. 26	Turn Hall	7:00	The Control Chart Method of Doing the Analysis of Variance	Miss Bonnie B. Small, Western Electric Co., Allentown, Pa.
	May 17	Turn Hall	7:00	The QC Engineer's Growth Towards Operation Research and Other Fields	W. D. Vinson, General Electric Co., New York, N. Y.
Tennessee	May 12	Alexander Hotel, Oak Ridge, Tenn.	7:30	.....	.....
Toronto	May 4	Univ. Toronto Elect. Eng. Bldg.	8:00	Selection of Samples for a Purpose	Miss Mary N. Torrey, Bell Telephone Laboratories, New York, N. Y.
	May 18	A. C. Wickman Co., 1425 Queensway, New Toronto	8:00	Plant tour	.....
Tucson	May 18	El Conquistador Hotel	6:30	Electronics Production Line Experimentation	Frank Caplan, Jr., Westinghouse Electric Corp., Blairsville, Pa.
Utica	May 19	Hotel Hamilton	5:00	Measuring Visual Characteristics	C. A. Reed, General Electric Co., Ashland, Mass.
Western Massachusetts	May 10	Sherton Hotel, Springfield, Mass.	6:30	Education Speeds the QC Gospel	Richard M. Story, University of Connecticut, Storrs, Conn.
Worcester	May 19	To be announced	7:00	Certain Aspects of Our National Security (Management Night)	Robert C. Sprague, Sprague Electric Co.
				Television Transmission (Ladies' Night)	Robert C. Clark, Ohio Bell Telephone

. . . Los Angeles—**Leo Aroian** recently left Hughes Aircraft as head of the mathematics section for a new assignment on the technical staff of Systems Technology Laboratories (STL).

Ray Crawford is now with Systems Development Corp., Santa Monica, Calif. He was formerly with Lockheed Aircraft Corp., Burbank, Calif., plant.

Howard C. Todt, past chairman of the section, formerly procurement QC manager, was recently elevated to assistant to the corporate director, **John Young,** for quality and logistics of NAA.

. . . Louisville—A two credit "QC Management Course," at the University of Louisville, one evening a week, began Feb. 6. **Allen Green** of the section is the instructor.

. . . Minnesota—**Tom Parenteau** and **Harlan Johnson** are now QC engineers with Minneapolis Honeywell, Ordnance Division. Both were formerly QC engineers with the Toni Co.

. . . Montreal—The following three members have been nominated as directors of the Montreal section — **J. Richer,** Johnson & Johnson; **W. L. Wingfield,** Trans Canada Air Lines, and **S. Thomas,** Northern Electric.

. . . Northeast Tennessee—A new evening study course in Elementary Industrial Statistics was started in Bristol on Feb. 18. Twenty-three persons enrolled in the course which is jointly sponsored by ASQC and State and City School Boards.

The section treasurer, **Myles Duellman,** S. E. Massengill Co., has been appointed a member of the National Defense Executive Reserve by the U.S. Secretary of Commerce.

The Northeast Tennessee section spearheaded the programs and activities for National Engineer's Week in the tri-city area of Bristol, Johnson City, and Kingsport, Tenn. A half hour television program was coordinated and presented with the aid of six other Engineering Society sections in the area. The subject of the program was "Engineering Benefits to Human Welfare —Past, Present and Future." **J. T. Johnston,** section vice chairman, of Raytheon Co., was moderator of the program. All newspaper, radio and television publicity was coordinated by ASQC members. Fourteen other engineering societies worked with the East Tennessee section in presenting a full week of engineering publicity and programs.

. . . Pensacola-Mobile—**L. J. Trahan** has been promoted to technical director of the Mobile Plant of the International Paper Co.

Jack F. Kilborn has been promoted to technical director of the Natchez plant of the International Paper Co.

. . . Pittsfield—**Frederick C. Hartwell,** past chairman, QC co-ordinator at the Schweitzer Mills of the Kimberly Clark Corp., presented a technical paper at the 45th Annual National Meeting of the Technical Association of the Pulp and Paper Industry, TAPPI.

. . . Rochester—**Colby H. Chandler** has been appointed general supervisor of technical services in the color print and processing organization of Eastman Kodak Co., an announcement made by **Clarence Wynd,** Kodak vice president and general manager of the Kodak Park Works.

. . . South Texas—The South Texas section is happy to announce that **A. C. H. Cook,** the new QC manager for the Lane-Wells Co., is a new member of ASQC.

. . . Southern Connecticut—Two more part-time instructors in the ranks of the Southern Connecticut section are **Howard Rosenberg,** at New Haven College, and Wright Technical Institute, and **Jack Riley,** at Danbury State Teachers' College.

. . . Washington, D.C.—**John A. Neal,** formerly with the Veterans Administration, has joined the staff of the Corporation for Industrial and Economic Research, Washington, D.C. Mr. Neal is secretary of the section.

John W. Tukey, professor of mathematics at Princeton University and assistant director of research, communication principles, Bell Telephone Laboratories, has been appointed to membership on President Eisnhower's Science Advisory Committee for the four-year term beginning Jan. 1, 1960.

. . . Worcester—**Nasim A. David** recently accepted the position of senior engineer, quality manufacturing department, Semi Conductor Division, Sylvania Electric Products, Woburn, Mass. He began work at Sylvania on Dec. 28, 1959. Mr. David was formerly with the Waltham Grinding Wheel Co., Waltham, Mass.

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A-16	Remington Rand Univac	49
A-17	Republic Steel	4
A-18	Sheffield Corp.	41
A-19	Thompson-Ramo-Wooldridge Products Co.	63
A-20	Veeder-Root, Inc.	57
A-21	Airborne Instruments Laboratory	59
A-22	Carl Zeiss, Inc.	5
A-23	American Optical	47

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CONTROL CHARTS WITHOUT CALCULATIONS

By PAUL C. CLIFFORD

State Teachers College, Montclair, N. J.

This Reprint from the May, 1959, issue, *Industrial Quality Control*, presents a method in which individual measurements are plotted, thus eliminating the data sheet. This procedure gives a simple comparison of process capability and process achievement.

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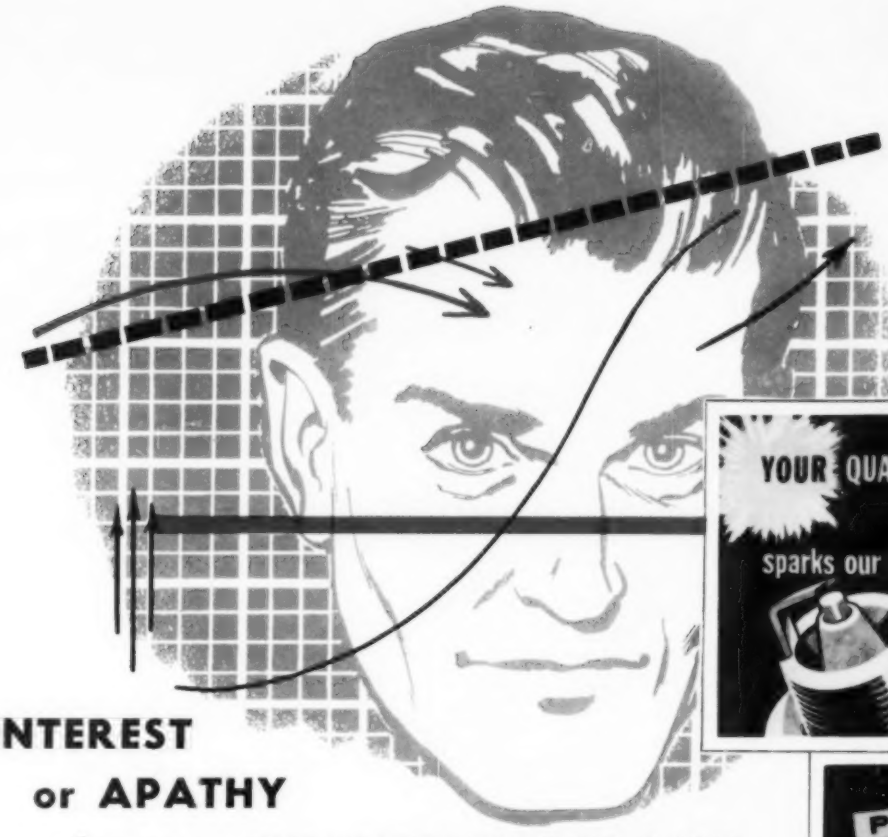

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